ISSN 2039-6651
Anno 2012_Numero 15

Miscellanea INGV

Riassunti estesi

Conferenza A. Rittmann

Nicolosi (Catania) 12 | 14 dicembre 2012

15

Istituto Nazionale di
Geofisica e Vulcanologia

ISSN 2039-6651
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miscellanea INGV

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a cura del Comitato Scientifico A. Rittmann

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Immagine di frontespizio

Il vulcano Etna in eruzione (foto di Thomas Reichart)

ISSN 2039-6651
Anno **2012**_Numero **15**

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Kinetics of crystal evolution as a probe to magmatism at Stromboli (Aeolian Archipelago, Italy)

Claudia Agostini[1], Andrea Fortunati[1], Fabio Arzilli[1,3], Patrizia Landi[2], Michael. R. Carroll[1]

[1]*Scuola di Scienze e Tecnologie, Sezione di Geologia, Camerino, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Italy*
[3]*Gruppo SYRMEP, ELETTRA Sincrotrone Trieste SCpA, basovizza, Trieste, Italy*

In this work crystallization kinetics of hydrated basaltic melts erupted during the present activity at Stromboli are studied for the first time, to estimate the growth and dissolution rate of plagioclase. A high-K basalt composition (PST 9-b) has been studied to investigate magma and eruption dynamics at Stromboli Volcano, combining crystallization kinetics of plagioclase and CSD measurements on natural samples.

A series of decompression experiments over a range of final pressure (Pf =100-5 MPa) at constant temperature (1075 °C) show that plagioclase is systematically present from 50 to 5 MPa in water-saturated conditions. Moreover, these experiments show that anorthite (An) content decreases with decreasing PH2O, reaching the same composition as the natural plagioclase in Stromboli scoria at pressure below ~20 MPa and that the plagioclase crystal fraction increases as the experimental conditions tend to lower final pressure. Plagioclase growth rate (GL) is observed to increase with undercooling, although at long experimental time (texp = 16 h), growth rates approach constant values. The values of GL vary from 10^-7 to 10^-8 cm/s for Pf from 75 to 25 MPa, while at Pf from 10 to 5 MPa growth rates are approximately of 10^-6 cm/s (slower in longer duration experiments). A series of dissolution experiments at atmospheric pressure and over a range of temperature has been done for plagioclase (T range of 1220 - 1240 °C). Dissolution rate (G-) for plagioclase (10^-7 cm/s) tends to be slightly higher at higher temperature in the range of 1220 - 1240 °C and appears to be time independent for the experimental durations investigated (10 - 30 h). These trends could be related to development of a diffusion-limited boundary layer adjacent to the dissolving crystal. By comparison of the experimental data on plagioclase composition, growth rates and dissolution in Stromboli basalt, it is possible to place the scoriae reservoir in the upper part (from ~ 500 m to the surface) of the volcanic conduit. Kinetic data of the plagioclase, the most important phase of the shallow magmatic system of Stromboli, show that the magmatic processes are quite dynamic and in a relatively short time (hours or several days) the system can changes considerably. Furthermore, the results from this work combined with observations on natural samples help to improve our knowledge of the magma plumbing system and of interactions between resident magma and new magma and in general the dynamics of volcanic activity of Stromboli and the time scales of magmatic processes that change from few hours to ~1 month.

The multidisciplinary study of the most active structures on Mt. Etna: the Pernicana and Trecastagni faults

Giampiero Aiesi[1], Alessandro Bonforte[1], Giuseppe Brandi[2], Francesco Calvagna[1], Salvatore Consoli[1], Giuseppe Falzone[1], Angelo Ferro[1], Salvatore Gambino[1], Francesco Guglielmino[1], Giuseppe Laudani[1], Franco Obrizzo[2], Giuseppe Puglisi[1], Benedetto Saraceno[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Italy*

Mount Etna has formed at the intersection of two regional fault systems, NNW-SSE and NE-SW trending respectively, and the complex interaction between regional stress, gravity forces and dike-induced rifting, seems to have a role in the eastward movement of the Mt. Etna eastern flank. In this context the Pernicana and the Trecastagni-Tremestieri Fault systems seem to identify the northern and southern boundaries of the unstable sector.

The Pernicana fault system is formed by discrete segments, arranged in a right stepping en échelon configuration, of a left-lateral shear zone that dissects the north-eastern flank of Etna. The kinematics of this system is related to shallow seismic crises (M~4.0) occurring along the western segment, with dip-slip displacement and left-lateral components. The eastern segment, ESE trending, is only affected by aseismic creep with purely left-lateral displacement.

The Trecastagni fault is a NNW-SSE tectonic structure developing on the lower southern flank, characterized by evident morphological scarps and normal and right-lateral movements that directly affect roads and buildings. This fault is affected by continuous dynamics with episodic accelerations accompanied with shallow seismicity.

The dynamics of these faults has been analyzed by a multi-disciplinary approach with terrestrial and satellite ground deformation data. Terrestrial data consist in levelling across both faults and extensometers record on the Trecastagni fault. Satellite data consist in InSAR data and GPS surveys on wide and local networks.

The leveling route on Mt. Etna is 150 km long and consists of 200 benchmarks. Part of the levelling route crosses the Pernicana fault, at an altitude of 1400 m asl. Measures on this network provide a high detail on the vertical kinematics allowing strong constraints in modelling the sources of slip episodes. A new levelling network has been installed across the Trecastagni fault and measurements showed a mean vertical slip rate of about 10 mm/y and episodic acceleration on short segments of the fault, with displacements of almost 30 mm.

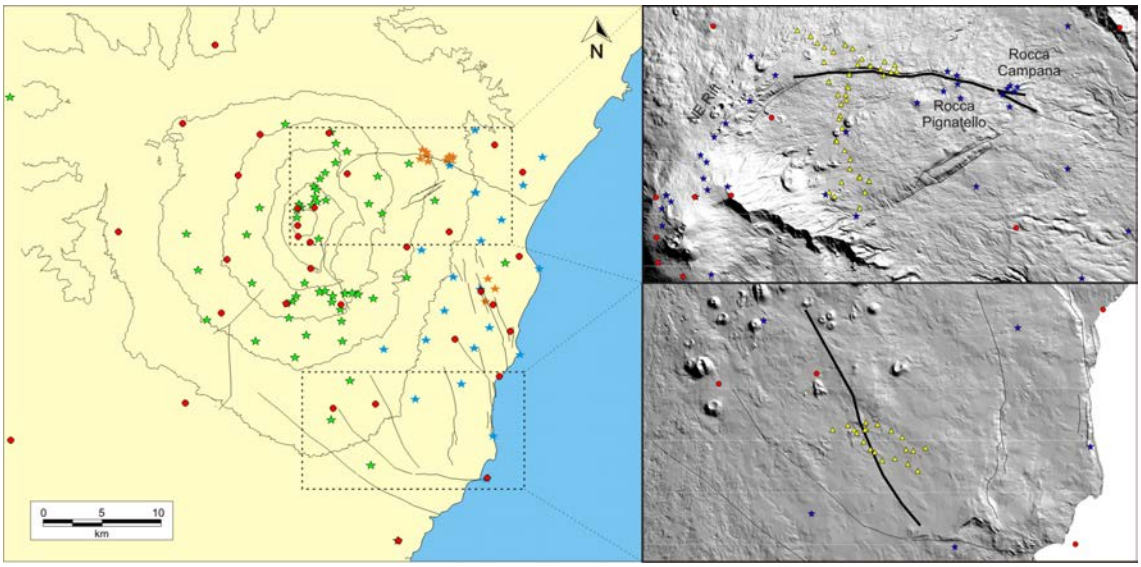

Figure 1. Map of the GPS networks (on the left): circles indicate permanent stations and stars represent benchmarks of the discrete networks. On the right, a zoom on Pernicana (top) and Trecastagni (low) faults; triangles indicate the levelling benchmarks.

The monitoring of the Trecastagni fault is also performed by two continuous wire extensometers and a system for periodic direct measurements across the fault in its central and north-central sectors. Each extensometer is equipped with a datalogger programmed for 48 data/day sampling, storing displacement and ground temperature. The two stations measure the relative displacements perpendicular to the fracture. Data recorded by extensometers highlight an opening trend of about 2-3 mm/year with some acceleration leading up to more than 2 mm in 15 days at the end of 2009.

Both faults show clear traces on SAR interferograms and PS time series. InSAR data allows tracking the path of the Pernicana fault from its connection to the NE rift to the coastline; the eastwards motion abruptly disappears north of the fault, producing a left-lateral transcurrent kinematics at a rate of about 20-30 mm/y. The Trecastagni fault shows a main vertical kinematics, with an evident downthrow of the eastern side at a rate of about 4 mm/y. Subsidence increase eastwards away from the structure, reaching a maximum rate of almost 10 mm/y. The fault produces a minor increase in the eastwards velocity on its eastern side evidencing also a minor extension of the structure. Episodic accelerations affect both faults and are visible on some interferograms from different sensors.

The dense GPS network is measured periodically and has more than seventy benchmarks. The time series of this network began in 1988 and from then on its configuration has been continuously improved. Two GPS networks lie across the eastern segment of the Pernicana fault. The first one, located in the “Rocca Campana” area, was installed in April 1997; the second one, located a few kilometers westward, in the “Rocca Pignatello” area, was measured for the first time in July 2002 upgrading an EDM network. The aim of these networks is to detail the structural framework and displacements along the aseismic sector of the Pernicana fault.

Integration of these wide spectrum of geodetic data allows strongly constrained ground deformation pattern to be defined and modeled. Furthermore, the very long time series available for the different datasets on the Pernicana fault, allows its behavior to be investigated in time and its role and relationships in the framework of flank instability and eruptive activity to better understood.

Querying volcano activity image database by indexing structure

Marco Aliotta[1,2], Andrea Cannata[2], Carmelo Cassisi[1], Placido Montalto[2], Michele Prestifilippo[2]

[1]Università di Catania, Dipartimento di Matematica e Informatica, Catania, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy

Explosive activity at Stromboli Volcano is routinely analyzed by live monitoring cameras in order to follow the eruptive dynamics. Since the style of strombolian activity can be monitored using frames acquired by video surveillance, an efficient system able to require information from a huge amount of frames is needed. Aim of this work is the development of a novel system capable of fast data retrieval based on similarity concepts. In the light of it, an indexing algorithm was developed. The concept is searching for elements of a set being close respect to a query element, according to a similarity criterion. To accomplish this task each video frame is processed using morphological image processing techniques to extract the image area of the explosion. Each closed curve, representing explosion contour, is approximated using an ellipse. The approximating ellipses are parameterized using the six coefficients of its general equation and then the evolution of each coefficient over time is expressed by the coefficients of their linear regression. All the linear regression coefficients, together with the six ellipse coefficients relative to the maximum expansion of the explosion, are the features describing the explosion sequence. Such features constitute the metric space in which similarity between objects can be evaluated calculating the distances by a given distance function. This approach suffers from an intrinsic problem related to the number of distance to be computed on a huge amount of data. To overcome this drawback, K-pole algorithm was applied. The basic concept is an indexing tree structure in which the number of distance to be computed among objects is minimized. K-pole allows us to perform a fast query execution (for example retrieval of the subset of objects similar to each other). The proposed system is able to find similar objects using distance among their features. Thus, we can group together explosions related to different kinds of activities using reference items. For instance, if we have a known image sequence, showing a given explosion, we can easily and quickly find all sequences containing explosions similar to it. Moreover, we can recognize video disturbances similar to a previously known one. Therefore, by this algorithm we can cluster the entire data space grouping objects that have similar characteristics.

Strain rate analysis and volcanic source modelling: an integrated approach to image volcano dynamics at Mt. Etna

Marco Aloisi, Valentina Bruno, Flavio Cannavò, Mario Mattia, Mimmo Palano, Danila Scandura

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy

We propose an analysis and modelling of continuous GPS data collected at Mt. Etna from February 2003 to December 2010. We use a dual-method approach: the inversion of the geodetic data to determine the volcanic sources acting inside the volcano and the strain rate analysis to image both tectonic and volcanic effects.

The analyzed period has been divided into nine different coherent phases: four inflation phases, three deflation phases and two phases characterized by a more complex deformation pattern. In particular, during the period 02 August 2008 - 14 June 2009 we observed the coexistence of a deflation of the summit area and an inflation at lower heights while the period 21 May 2010 - 31 December 2010 was characterized by an inflation at medium height without significant areal deformation changes at the summit.

Analytical models indicate a non-uniform deformation style revealing spaced sources acting at different time on different segments of a multi-level magma reservoir. The imaged Etnean plumbing system is depicted as an elongated magma reservoir that extends from the volcano body downwards to about 8.0 km below sea level (b.s.l.), sloping slightly towards the North-West, with storage volumes located at about 8.0, 4.0 and 2.0 km (b.s.l.). The high quality of data collected on the dense configuration of the Etn@net CGPS network permits a detailed analysis of the mechanisms of magma migration from depth and, therefore, allows a fast and accurate evaluation of volcanic hazard. In particular, the analysis proposed here highlights some significant characteristics: 1) the inflation pressure sources are located between the eastern border of the low vp velocity zone and the western border of the high vp velocity zone, coherently with the path along which the magma rises; 2) the deflation pressure sources are located to the East with respect to the inflation sources, just below the Central Crater area; 3) the inflation sources are characterized by a more elongated shape respect to the deflation sources showing an almost spherical shape; 4) the inflation sources undergo a progressive deepening in time; 5) during a generally non-homogeneous phase (either deflation and inflation recorded at different altitudes at the same time) it is possible to envisage, for the first time on Etna Mount, different sources contemporaneously acting beneath the volcano.

The deformation pattern recorded during the analyzed period strongly suggests a double origin of magma overpressure: 1) the gas exsolution and boiling caused by a relative increase of the content of volatiles in residual magma during crystal fractionation process occurring within the magma chamber and/or magma conduits or by the fluid migration irrespective of magma; 2) the progressively rising toward the surface of batches of magma.

Moreover, we show that the kinematics and the ground deformation pattern observed on Mt. Etna are strongly influenced by the south-eastward motion of the eastern flank. In particular, the south-eastward directed motion prevails over the effects due to magmatic sources in the lower eastern flank, while the mid-upper eastern flank is clearly driven by the interplay between the two different components.

The joint use of the strain rate maps with the modelling of pressure sources acting inside the volcano has allowed us to distinguish and quantify the volcanic deformations from deformations of different origin, which has always been a crucial question in the study of the crustal deformations of Mt. Etna.

Our modelling of the geodetic velocity field has clearly showed an area of clockwise rotation which extends in the eastern flank, bounded approximately to the North by the North-East Rift and the Pernicana fault system, to the North-East by the Ripe della Naca fault scarps and to the East by the Timpe fault system. This area is characterized by a low internal shear strain rate and is bounded by higher shear strain values.

Finally, the accordance between the higher geodetic shear strain rates and the area with the highest seismic energy release shows that measured geodetic shear strain rates can provide useful information on the potential occurrence of seismic activity on Mt. Etna Volcano.

A dense seismic network along a capable fault: an application to the eastern sector of the structural system of the Pernicana-Provenzana (Mt. Etna, Sicily, Italy)

Salvatore Alparone[1], Danilo Contrafatto[1], Giacomo Dario D'Amico[2], Graziano Larocca[1], Ferruccio Ferrari[1], Salvatore Rapisarda[1], Luciano Scuderi[1], Orazio Torrisi[1], Andrea Ursino[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*Ministero della Giustizia, D.G.S.I.A., Coordinamento Interdistrettuale Sistemi Informativi Automatizzati di Catania, Italy*

The Provenzana-Pernicana System (PPS) is one of the most active tectonic lineaments of Mt. Etna [Azzaro et al., 1998, 2012]. Its eastern extension is the subject of extensive scientific debate about its seismotectonic features . Overall, this system, which develops to the Ionian Sea with a total length of about 18 km, is considered the northern boundary of an unstable sector that includes most of the eastern flank of the volcano [Borgia et al., 1992, Lo Giudice and Rasà, 1992]. In particular, the movement of the PPS is accommodated towards the east, beyond the village of Vena, with minor faults which together define the Eastern Provenzana-Pernicana System (EPPS). The PPS has an E-W trend, which is in a marked contrast with the orientation of the main structural trends in the Etnean region [Rasà et al., 1982; Azzaro et al., 1988]. In addition, it may be considered a capable fault, namely an active fault with clear historical and geological evidences indicating the possibility of significant surface movements in the near future [Azzaro et al., 1998]. The PPS primarily has a left lateral kinematic, clearly visible to the west of the village of Presa and it moves both in a coseismic way and by aseismic creep with a high slip rate [Azzaro et al., 1998; Tibaldi and Groppelli, 2002]. In particular, the PPS system is seismically active until the village of Vena-Presa and is characterized by an extremely shallow seismicity (H<3 km) with earthquakes reaching values of magnitude up to 4.3 [Azzaro, 1997; Alparone et al., 2012; Gruppo Analisi Dati Sismici, 2012]. Otherwise, the EPPS is characterized by a low occurrence rate of earthquakes and by movements related to aseismic creep that sometimes cause damage to existing structures (roads, houses, highways, pipelines).

In order to improve the detection capacity of the permanent seismic network managed by Istituto Nazionale di Geofisica e Vulcanologia – Osservatorio Etneo - Sezione di Catania and to study the seismicity of the EPPS in great detail, a project that envisages the installation of a dense local seismic network for medium-long periods in the vicinity of such structure has been designed for the first time. The study of the seismicity along the EPPS will be made through the use of digital Lennartz PCM Encoder 5800 stations with a system of remote transmission and decoding and equipped with three-component sensors. The average distance between stations is approximately two kilometers. The complete installation will comprise a total number of nine stations. This instrumentation will enable investigating the possible micro-seismic activity along the EPPS. In particular, we intend to verify if the movements, which from literature data seem to be aseismic (creep), are indeed associated with a micro-seismicity that is not detectable by the permanent seismic network. In this paper, we will focus on the technical aspects of the installation of this local seismic network along this important sector of the volcano.

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Instrumental seismic catalog of Mt. Etna (Sicily, Italy) in the period between 2000 and 2010

Salvatore Alparone, Vincenza Maiolino, Antonino Mostaccio, Antonio Scaltrito, Andrea Ursino, Graziella Barberi, Salvatore D'Amico, Elisabetta Giampiccolo, Carla Musumeci, Luciano Scarfì, Luciano Zuccarello

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy

Mount Etna, one of the most active basaltic volcanoes and among those most highly monitored in the world, has a remarkable seismic and volcanic activity. It is located in eastern Sicily, in a complex geodynamic framework, where the main regional tectonic structures play a key role in the dynamic processes of the volcano. The seismicity of Mt. Etna is characterized by a high rate of earthquakes of low and moderate energy, owing to the shallowness of the source, sometimes causing damage to towns nearby the epicentral area. The systematic monitoring of Etnean seismic activity has been carried out since 1989 by a local permanent seismic network, currently managed by Istituto Nazionale di Geofisica e Vulcanologia - Osservatorio Etneo - Sezione di Catania, which over time has been the subject of significant improvements both on the number of stations installed on the volcano and the technology used for data acquisition. At present, the seismic network consists of about 50 stations equipped with three component broadband sensors. A dense local seismic network also allows locating earthquakes characterized by low energy ($M \geq 1.0$), useful for both surveillance and monitoring as well as research activities. This aspect is important in a volcanic environment where the seismicity occurs in the form of swarms rather than with mainshock-foreshock distribution.

Instrumental seismic catalogs are an essential tool for the seismic zonation of the territory and the preparation of maps of seismic hazard.

In this study, we present the first catalog of Etnean seismicity during the period between 2000 and 2010. This is the result of a working group that analyzes and locates the earthquakes occurring in the Mt. Etna area, providing detailed information on the spatial and temporal evolution of seismicity [Gruppo Analisi Dati Sismici, 2012].

In the analyzed period, we located more than 6300 events corresponding to approximately 40% of the earthquakes recorded. In addition, the catalog of earthquakes is made up of about 3900 events with a threshold of magnitude completeness equal to 1.6.

The good quality of the data collected in this catalog is supported by the values of the location parameters. Indeed, 64% of located events show an RMS (root mean square) less than or equal to 0.15 seconds, hypocentral errors on the distance and depth , are as a percentage equal to 80% within the kilometer and also an azimuthal gap is as a percentage equal to 80% within 180°. All earthquakes were located with the Hypoellipse algorithm [Lahr, 1989] and 1D crustal velocity model [Hirn et al. 1991].

This catalog allows defining, with great detail, the main seismogenic areas of the volcano related both to regional tectonics and magma dynamics. It represents a valuable and indispensable tool for all monitoring and research activities undertaken in the Mt. Etna area.

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The 2011-12 sequence of lava fountains at Mt. Etna Volcano: insights into the explosive processes and associated deposits

Daniele Andronico[1], Antonio Cristaldi[1], Ferruccio Ferrari[1], Matthias Jauvin[2], Deborah Lo Castro[1], Simona Scollo[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*Ecole et Observatoire des Sciences de la Terre, Strasbourg CEDEX, France*

In the last years, Mt. Etna Volcano has displayed a high number of paroxysmal events and long-lasting explosive eruptions. Classifying the different eruption types and defining the explosive styles are important tasks aimed at improving the general knowledge of the basaltic volcanism and the eruption dynamic. This goal may be achieved by outlining the volcanological and geophysical parameters which control the relatively wide spectrum of explosive activity and their mutual correlations, like eruption column height, RMS (Root Mean Square) tremor amplitude, mass eruption rate, and the textural features of the tephra fallout deposit.

South-East Crater (SEC) is one of the four summit craters of Etna and one of the most active volcanic craters in the world. It is renowned for its episodic eruptions [Alparone et al., 2003, 2007; Andronico et al., 2009; Andronico and Corsaro, 2011], consisting of outstanding sequences of lava fountains [Andronico et al., 2008]. The last sequence took place between 12 January 2011 and 24 April 2012, when twenty-five lava fountains occurred, typically producing 2-3 km-height eruption columns and fallout deposits over distances up to several tens of km from the vent. The sequence is well represented by the temporal distribution of the RMS tremor amplitude, in which each lava fountain episode identifies an increase of tremor.

We first review this type of episodic activity by highlighting their general volcanological features in terms of cyclicity, volcanic pattern and eruptive dynamic, and then summarize the main volcanological features of the 2011-12 sequence of lava fountains.

Figure 1. Tephra fallout deposit covering a portion of the wide depression known as 'Valle del Bove' in the E side of Mt Etna (photo by D. Andronico).

All data collected in 2011-12 provided the opportunity to preliminarily characterize most of the paroxysms and related fallout deposits. Surveys were carried out for most of the episodes in order to sample and map the associated fallout deposits. Field observations and laboratory measurements (grain-size, morphological and componentry analysis) allowed to characterize the tephra deposits, providing a preliminary evaluation of the total erupted mass. By mapping the fallout dispersal of all the episodes, we show the frequency distribution of tephra deposits around the volcano, highlighting that the 2011-12 lava fountains affected mostly the areas between E and S. While the proximal deposit (up to 1-1.5 km from the vent) is formed by a decimetric- to centimetric-thick tephra blanket containing scoriae to coarse lapilli, the texture of the intermediate to distal products is characterized by abundant, relatively coarse ash almost entirely composed of sideromelane particles. Analysis of data collected on the 2011-12 events, together with classification of most of the episodes within the Walker classification scheme, provide clear insights into the eruptive style and dynamics of lava fountains at Etna and shows that, despite having similar volcanic pattern, the different episodes were differently sized in terms of released seismic energy and mass of erupted tephra.

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Can GPS detect volcanic plumes on Mount Etna?

Massimo Aranzulla[2], Flavio Cannavò[1], Simona Scollo[1], Giuseppe Puglisi[1], Giuseppina Immè[2]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*Università di Catania, Dipartimento di Fisica e Astronomia, Catania, Italy*

In recent years the Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, has developed a permanent and continuous GPS network in order to study the ground deformation of Mt. Etna, in Italy. The GPS network consists of 35 permanent stations located on the volcano flanks that are able to detect, in near-real time, small ground displacements of order of centimeters [Palano et al., 2010]. However, it has been demonstrated that GPS is also able to detect volcanic plumes [Houlie et al., 2005]. For Etna, data coming from nineteen GPS receivers between 5 August (day-of-year 217) and 4 September (day-of-year 247) 2007, have been already analyzed and the results have shown the volcanic plume affects the GPS undifferenced post-fit phase residuals [Aranzulla et al., 2012]. In fact the electron plasma and neutral atmosphere, water vapor, hydrometeors and particulates induce propagation path delays in the GPS signal. This delay is quite accurately modeled and measured from each GPS satellite for elevation angles above about 15 degrees. We processed the GPS data coming from the Etna network using the GAMIT package developed by Massachusetts Institute of Technology [Herring et al., 2010]. This software uses doubly differenced GPS phase observations to estimate for each observing span a single set of station positions and orbital parameters together with piecewise linear models of atmospheric zenith delay and gradients for each station. After estimating station positions and atmospheric parameters from the doubly differenced phase, GAMIT can produce residuals for the undifferenced phases by estimating clock corrections which cancel in the double-differences. We use these undifferenced post-fit phase residuals as input in testing for the presence of a volcanic plume. Firstly we realize a simplified model representing the volcanic plume in atmosphere and evaluate the GPS satellites and stations that crossed the computed volcanic plume. Furthermore, we use of a robust statistical model combing different parameters to fix some thresholds and gives the certainty that GPS detects the volcanic plume with 99% of confidence. The method is applied to some lava fountains activity occurred during 2011-2012. In the analyzed period Etna produced more than twenty lava fountain episodes forming, in the most intense phase, volcanic plumes from few to tens kilometers of altitude. We retain that GPS stations could be complementary to the already existing monitoring system of Etna volcanic plumes.

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The volcano-tectonic map of Etna Volcano, 1:100.000 scale: an integrated approach based on a morphotectonic analysis from high-resolution DEM constrained by geologic, active faulting and seismotectonic data

Raffaele Azzaro[1], Stefano Branca[1], Klaus Gwinner[2], Mauro Coltelli[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*German Aerospace Center (DLR), Institute of Planetary Research, Berlin, Germany*

A new volcano-tectonic map of Etna Volcano, scale 1:100.000, has been compiled through a morphotectonic analysis performed with detailed field mapping, high-resolution DEM and orthoimages, constrained by seismotectonic data.

In this study, we present a homogeneous mapping of the volcano-tectonic and tectonic elements on the whole volcano, consistent with the updated knowledge on the geology and active tectonics observed in historical times. Details of the tectonic features occurring in the lower-middle part of the volcanic edifice, namely the more densely urbanized areas, are described; volcanic elements such as eruptive fissures, caldera and flank collapse rims affecting the upper sectors, are also reported. All the volcanic landforms of Etna edifice have been generated by constructive and destructive volcanic processes largely during the last 15 ka activity of Mongibello Volcano. In particular, the destructive processes are related to two caldera collapses, Ellittico and Il Piano, occurring about 15 ka and 2.1 ka ago respectively, and to a huge flank collapse that formed the wide horseshoe shaped depression of the Valle del Bove about 10 ka ago. The volcanic processes of magma intrusion produced eruptive systems (fissures and pyroclastic cones) mainly during the past 15 ka. Their distribution and the orientation show a clustering of vents following three main rift zones that are also closely connected with some fault systems dissecting the volcano edifice.

Tectonic landforms include elements characterised by both permanent morphology and short-lived features produced by active faulting (hidden faults). DEM-derived images (e.g. slope and aspect maps) were produced and interpreted in order to identify fault related surface features based on an explicit list of well-known elements of tectonic geomorphology. Subsequently, the morphotectonic mapping has been compared with field data on geologic marker offsets, as well as evidence of surface faulting, including coseismic displacements and creeping of historical and recent events (Figure 1). This combined approach has enabled classifying each

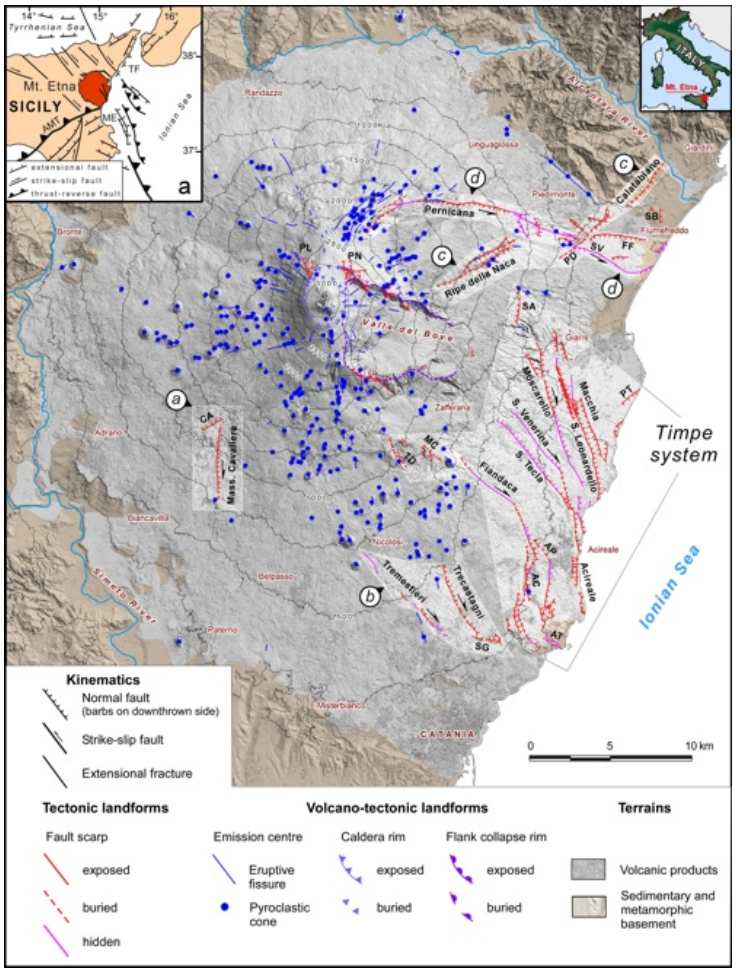

Figure 1. Volcano-tectonic map of Mt Etna [after Azzaro et al., 2012]. Fault abbreviations: a, Ragalna system; b, Tremestieri-Trecastagni-system; c, Ripe della Naca-Piedimonte-Calatabiano system; d, Pernicana system; AC, Acicatena; AP, Aciplatani; AT, Acitrezza; CA, Calcerana; FF, Fiumefreddo; MC, Mt. Cicirello; PD, Piedimonte; PL, Punta Lucia; PN, Pizzi Deneri; PT, Praiola-Torre Archirafi; SA, S. Alfio; SB, Serra S. Biagio; SG, S. Gregorio; SV, S. Venera; TD, Tardaria.

element reported in the map as (i) exposed faults, (ii) buried faults and (iii) hidden faults. The analysis of slip-rates confirms the exceptional dynamics of the Pernicana fault, which is characterised by an almost constant slip-rate of 20-36 mm/a over the last 1000 years, while the Timpe fault zone and the structural system in the southern flank accommodate a relevant amount of deformation with slip-rates reported to range of ca. 2-4 mm/a. Finally, a seismotectonic model summarises the information regarding seismic hazard, with reference to the additional, potentially severe effects induced by surface faulting. The obtained seismotectonic model finally provides an additional contribution to the Volcano-tectonic map of Etna, displaying the hazard induced by the faults in a region characterised by a high frequency/short recurrence time of damaging earthquakes and widespread phenomena of surface faulting.
On the whole, the new Volcano-tectonic map of Etna represents the state-of-the-art on the knowledge of the structural setting of the volcano, providing an upgraded cartographic document in which all mapped elements are consistent with each other and are constrained by different methodological approaches.

The effect of Etna volcanic ash plumes on the Maltese islands

Francelle Azzopardi[1], Raymond Ellul[1], Michele Prestifilippo[2], Simona Scollo[2], Mauro Coltelli[2]

[1]*University of Malta, Physics Department, Msida, Malta*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*

In this paper we studied in depth the effect of Etna volcanic ash plumes on the Maltese Islands. Research was carried out to gather information about Etna's eruptions which involved the Maltese Islands, starting with historical eruptions dating back to the 14th century to more recent ones. A statistical approach was utilized to provide tephra deposit load and ash concentration using PUFF – a model which simulates the transport, dispersion and sedimentation of volcanic ash. Three different eruptive scenarios that characterize Etna's recent activity were considered; the first scenario representing the 2001 eruption (S1), the second scenario representing the 1998 eruption (S2) whilst the third scenario represents the recent activity in 2011-2012 (S3). We found that the time taken for the volcanic ash plume to reach the Maltese Islands when the wind direction is towards the South West ranges from 4 to 8 hours and the probability that Etna volcanic plume reaches Malta during an eruption is about 15%. The calibrated model, daily producing deposit load and cumulative area of volcanic ash dispersal, will be thus allowing provision of adequate alerts to civil aviation authorities and Malta airport. This will be of direct use to local communities and air traffic.

The inner structure of Etna Volcano through local earthquake tomography

Graziella Barberi[1], Ornella Cocina[1], Pasquale De Gori[2], Elisabetta Giampiccolo[1], Domenico Patanè[1,3], Simona Sicali[1,4]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Centro Nazionale Terremoti, Roma, Italy*
[3]*Istituto Andaluz de Geofísica, Campus Universitario de Cartuja, Granada, Spain*
[4]*Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Catania, Italy*

In the last decade, several seismological studies on the inner structure of Etna Volcano have been carried out using different tomography techniques and a variety of datasets.

In recent times the continuous seismic and volcanic activity and the use of a large number of permanent seismic stations, has permitted the definition of high resolution 3D velocity and attenuation models. The distribution of the velocity and attenuation anomalies under the volcano allowed to put some constraints on the location of magma volumes and on volcano dynamics during and before the eruptions. Here, we present the state of knowledge on the inner structure of Etna Volcano derived from local earthquake tomography, both in velocity and attenuation. A joint study of velocity and attenuation models is very useful to understand the physical processes involved in an active volcano, like Etna. In particular, the attenuation of body waves is very sensitive to the thermal state of the crustal volume through which seismic waves travel, and to the saturation of rocks with fluids and partial melts. The new 3D velocity and attenuation structure, derived from seismic tomography inversions using the seismicity localized at Etna Volcano during 1994 – 2008 interval time, will be also presented. About 4,000 earthquakes have been inverted using a new double-difference (DD) seismic tomography code [tomoDDPS by Zhang et al., 2009] which simultaneously solves for earthquake locations and velocity model using both absolute and differential P, S, and S-P times. The 3D QP structure, has been calculated by using the Thurber [1993] code modified for attenuation by Rietbrock [2001].

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Lava-snow/ice interactions during the 2011-2012 summit eruptions of Mount Etna

Boris Behncke[1], Daniele Andronico[1], Maria Deborah Lo Castro[1], Giovanni Tomarchio[2]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*RAI, Catania, Italy*

During recent decades, high-eruption rate episodes producing tall lava fountains, tephra-rich eruption columns, and fast-moving lava flows have been the most common typology of summit eruptions at Mount Etna, Sicily. Until recently, the recognized hazards related to this type of activity were pyroclastic fallout near the vent and downwind, volcanic ash plumes interfering with air traffic, and lava flows threatening man-made objects (tourist infrastructures, volcano surveillance instruments). To these, a previously unappreciated hazard has to be added: interaction of lava with snow and/or ice on the ground.

The latest series of 25 paroxysmal episodes at Etna took place between January 2011 and April 2012 from a new vent on the eastern side of the Southeast Crater, in the summit area of the volcano, delivering lava flows to the southeast (into the Valle del Bove), northeast, and south. At least 10 of these events took place while the upper slopes and summit of Etna were covered with snow and were accompanied by intense interactions between fast-moving lava flows and thick snow and/or ice – strong hydromagmatic explosions that generated lahars and fast-moving, ground-hugging ash and vapor clouds resembling pyroclastic flows. Two cases were particularly well observed and documented in photographs and video, on 10 April 2011, and on 4 March 2012, and the ash-and-vapor cloud deposits of 4 March 2012 were sampled and analyzed.

In both cases, major explosions occurred when rapidly flowing lava encountered thick snow in relatively narrow depressions and on steep slopes, where lava mixed with rapidly melting snow. On 10 April 2011, hydromagmatic explosions started with a series of increasingly powerful puffs of vapor and gray ash, later also blocks. The strongest explosions produced low columns of ash and vapor that collapsed onto the ground, transforming into ground-hugging clouds that traveled up to 1.5 km from the source, which itself was located about 1.5-2 km from the active vents. The speed of these clouds was at least several tens of kilometers per hour. Movie footage shows that the basal portion of the ground-hugging cloud consisted – at least in part – of lava and snow and/or meltwater that continued to mix and interact explosively. As the ash-and-vapor clouds slowed, the basal flows were seen to advance further as hot lahars. Some lahars reached the flat bottom of the Valle del Bove, at the base of its steep western slope.

On 4 March 2012, an eruptive fissure opened on the southern slope of the Southeast Crater cone, releasing a voluminous lava flow that plunged into a narrow depression filled with snow at the base of the slope. Explosive interaction generated a large vertically rising ash and steam

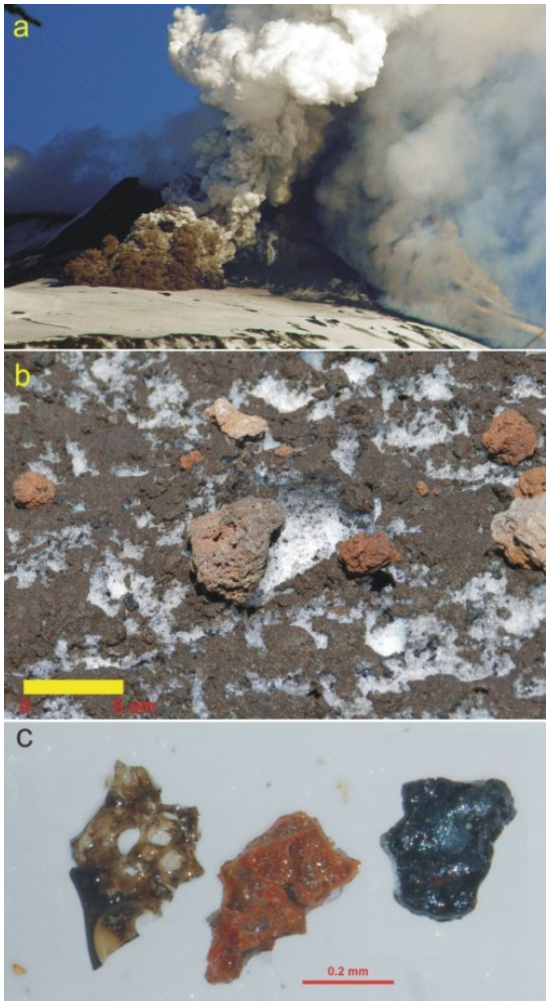

Figure 1. a) Ash-and-vapor cloud advancing on gently sloping terrain at the southern base of the Southeast Crater cone on 4 March 2012.
b) Deposit of the 4 March 2012 ash-and-vapor cloud approximately 0.3 km south of the source of the hydromagmatic explosions that generated the cloud (photo by B. Behncke).
c) The three main types of ash particles found in the coarse-grained ash matrix of the deposit (photo by M.D. Lo Castro).

plume, and a series of progressively more ash-rich, ground-hugging ash-and-vapor clouds (Figure 1a) that advanced in a pyroclastic-flow-like fashion over gently sloping terrain, traveling first south and then being deflected toward southeast by a low (<10 m) ridge before slowing to a halt at a distance of about 1 km from the explosion site. The basal lahar continued to advance much further, spilling about halfway down the steep western face of the Valle del Bove.

The deposit of the 4 March 2012 ash-and-vapor cloud, sampled at a distance of about 0.3 km from the source of the hydromagmatic explosions (Figure 1b), consisted of a coarse-grained ash matrix (90 % between 0.125 and 1 mm). The matrix is composed of light, nearly blocky sideromelane, shiny tachylite and reddish scoriaceous ash particles (Figure 1c) with similar percentages, and scattered reddish lapilli-sized clasts floating on top of the ash deposit (Figure 1b).

Here we present preliminary studies on this type of basaltic explosive deposit in order to understand its eruption dynamics, assess potential volcanic hazards posed in the proximity of the eruptive vent, and suggest a terminology well-depicting the volcanic phenomena producing the deposit itself.

The 2011-12 summit activity of Etna: growth of the new SE crater and petrochemistry of the products

Boris Behncke, Stefano Branca, Rosa A. Corsaro,
Emanuela De Beni, Lucia Miraglia, Cristina Proietti

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy

Between January 2011 and April 2012, the Southeast Crater on Mount Etna was the site of 25 episodes of lava fountaining, which led to the construction of a new pyroclastic cone on the eastern flank of the old cone of the same crater. The new cone grew over a pre-existing subsidence depression ("pit crater"), which had formed in November 2009 and progressively enlarged in a series of collapses during the following months. The evolution of the cone was documented from its start by means of movie footage recorded by the monitoring cameras of the INGV-Osservatorio Etneo, the acquisition of comparison photographs, and repeated GPS surveys carried out both from a distance, and on the cone itself. These surveys reveal that after the cessation of the lava fountains in April 2012, the highest point of the cone stood about 200 m above the pre-cone surface, and its volume was about 17 x 10^6 m3, almost one-third of the total volume of volcanic products erupted in 2011-2012 (60 x 10^6 m3).

Figure 1. Comparison photographs showing the development of the New Southeast Crater from a steaming pit in November 2010 (top) to a pyroclastic cone about 200 m tall in April 2012 (bottom). Photos were taken from about 1 km distance to the southeast.

The cone initially grew around a small cluster of closely-spaced vents within a single crater, remaining open on the southeastern side where the crater rim was lowest and lava exited during each lava fountain. From late-August 2011 on, the breach in the southeastern crater rim was also the site of a short eruptive fissure that opened during most episodes and produced lava fountains from several aligned vents. A few vents also erupted outside the crater on the northern flank of the growing cone in late-2011 and early 2012.

The growth of the new cone took place exclusively during the paroxysmal phases of the lava fountaining episodes, which were nearly always rather brief (on the average 2 hours). Put together, the paroxysmal phases of all 25 episodes represent 48 hours of lava fountaining activity – the time necessary to build the cone. This is the fastest documented growth, both in terms of volume and height, of a new-born volcanic cone. The famous Parícutin (Mexico) in 1943 grew to 150 m height in a week; at Etna in 2001, the "Laghetto" cone reached a height of slightly less than 100 m and a volume of about 5 x 10^6 m3) in 6 days of activity. Mass eruption rates during the lava fountaining phases of 20 August 2011, 29 August 2011, 8 October 2011 and 24 April 2012 exceeded 500 m3 s^-1 and are thus among the highest ever recorded at Etna.

Another kind of "volcanic risk": the acidification of sea-water. Vulcano Island (Italy) a natural laboratory for ocean acidification studies

Fulvio Boatta[1], Walter D'Alessandro[2], Lisa Gagliano[1], Sergio Calabrese[1], Marcello Liotta[2], Marco Milazzo[1], Francesco Parello[1]

[1]*Università di Palermo, Dipartimento Scienze della Terra e del Mare, Palermo, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy*

Acidification of seawater is one of the aspect tightly linked to volcanic risk, due to the presence of submarine vents releasing abundant volcanic fluids. In aquatic system CO2 gas dissolves, hydrates and dissociates to form weak carbonic acid, which is the main driver of natural weathering reactions [Drever, 1997]. The result of the CO2 increase is seawater acidification.
Vulcano Island, the southernmost of Aeolian Islands, is located in the Southern Tyrrhenian Sea (Italy), approximately 18 miles off the NE coast of Sicily. The Baia di Levante can be considered a natural laboratory where almost all of the biogeochemical processes related to the ocean acidification can be studied. In this area many submarine vents release CO2. Four geochemical surveys of the Bay were carried out in April - September 2011 and May - June 2012. The main physic-chemical parameters (T, pH, Eh, electric conductivity) were measured at more than 70 sites and more than 40 samples for chemical analyses were collected at representative points. Major (Na, K, Mg, Ca, Cl, SO4) and some minor components (B, Sr, Fe) and trace elements (Mn, Mo, Al, U, Ce, Pb, Tm, Tb, Nd, Th) dissolved in water, the chemical composition of dissolved gases (He, H2, O2, N2, CH4 and CO2) and the isotopic composition of total dissolved inorganic carbon were determined in the laboratory. The bubbling CO2 produces a strong decrease in pH from the normal seawater value of 8.2 down to 5.5 (Figure 1). In the area close to the main degassing vents, characterized by very low pH, macroorganisms were absent.
Acidification of sea water is one of the aspect tightly linked to volcanic risk, due to the presence of submarine vents releasing abundant volcanic fluids.
At Baia di Levante, about 300 m from the main vents the seawater is only slightly acidic (pH 6.5 - 7.0) resembling the ocean water conditions in equilibrium with the high atmospheric CO2 concentrations expected in the near future. Therefore environments like this, naturally enriched in CO2, are good laboratories to study the consequences of ocean acidification on aquatic biota [Doney et al., 2009].
Furthermore acidification is tightly linked with the mobility and bio-availability of heavy metals [Millero et al., 2009] in sea water and volcanoes were always the favourite choice for human settlements; as a consequence economic anthropological activity, such as fishing, could be dangerous for human health, because of the presence toxic level of trace metals in the food chain due to the presence of the volcano's.
The present study could provide important information about the best environmental management of volcanic areas such as Vulcano Island.

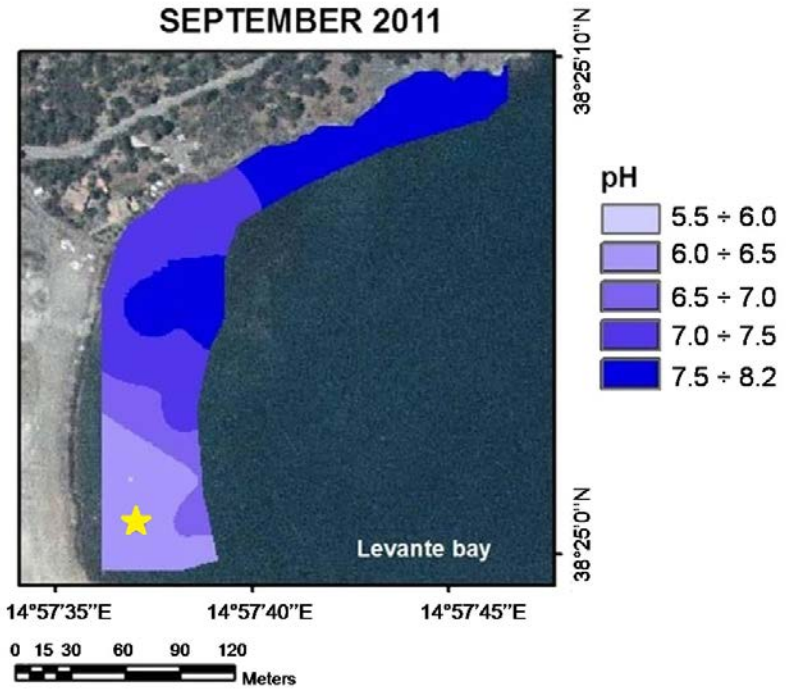

Figure 1. The bubbling CO2 area which produce the pH gradient in "Baia di Levante". The yellow star is the main gasses emitting point.

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Determination of the largest clast sizes of tephra deposits for the characterization of explosive eruptions: a study of the IAVCEI Commission on Tephra Hazard Modelling

Costanza Bonadonna[1], Raffello Cioni[2], Marco Pistolesi[3], Chuck Connor[4], Simona Scollo[5], Laura Pioli[1], Mauro Rosi[3]

[1]*University of Geneva, Switzerland*
[2]*Università di Cagliari, Dipartimento Scienze Terra, Cagliari, Italy*
[3]*Università di Pisa, Dipartimento Scienze Terra, Pisa, Italy*
[4]*University of South Florida, USA*
[5]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*

The IAVCEI Working Group on Modelling Volcanic Tephra-Fall Hazards was born to integrate and improve current hazard approaches and tephra-dispersal models. Given that comprehensive hazard assessments are based on a detailed characterization of tephra deposits, one of our goals is to assess the limitations of field techniques and produce standard methods for the determination of field parameters. During the third meeting of this IAVCEI Commission we have focused on the determination of the maximum clast (Ecuador, Cities On Volcanoes 2006), which is typically used for the calculation of column height and wind speed at the time of the eruption. In particular, the column height represents a crucial eruptive parameter that can be used to define the eruption style and the mass eruption rate. However, the "maximum clast" is a controversial concept and often even the same scientists have applied different techniques to different deposits. The most common methods used are the average of maximum axis of the three largest clasts, the average of maximum axis of the five largest clasts, and the average of three axes of the five largest clasts. The application of different techniques generates different isopleth maps and therefore can significantly affect the determination of column height and wind speed. For this reason, we have compared different techniques on two outcrops of a massive andesitic-pumice layer produced by a Cotopaxi eruption around 800 years ago (Ecuador). The two outcrops were selected at different distances from the vent in order to investigate the effect of grainsize variations on the determination of the maximum clast. The participants of this workshop were divided into five groups and different averaging techniques were applied on different outcrop areas. We found that discrepancies due both to the use of different averaging techniques and to the sampling of different areas by different groups are of similar scale of clast dimensions and therefore smaller grainsizes are characterized by smaller standard deviations with lithics showing the narrowest data spread. In addition, a statistically representative sampling area depends on the outcrop grain-size and lithic content. We introduced the method of the 50th percentile of a population of 20 clasts as it represents the best way to assess the largest clasts because it has the advantages of: i) eliminating the problem of outlier identification, ii) offering a more reliable reproducibility of the characterization of a given outcrop than the measurement of a small population of large clasts. Suggestions on the selection of sampling area, collection strategy, choice of clast typologies and clast characterization (i.e., axis measurement and averaging technique) are also given.

U-series isotopes in the present-day activity of Stromboli Volcano: constrains on the plumbing system

Alessandro Bragagni[1,2], Riccardo Avanzinelli[1,3], Lorella Francalanci[1,4]

[1]*Universitá degli Studi di Firenze, Dipartimento di Scienze della Terra, Firenze, Italy*
[2]*Universitaet Bonn, Steinmann Institut, Bonn, Germany*
[3]*University of Bristol, Department of Earth Sciences, Bristol, UK*
[4]*CNR, Istituto di Geoscienze e Georisorse, Sezione Firenze, Italy*

U-series isotopes represent a unique opportunity to study volcanic systems since they provide constraints on mantle melting and on timing of shallow magmatic processes. Particularly, parent-daughter isotopes pairs with different half-lives (e.g. 230Th-238U; 226Ra-230Th) are able to unravel processes at different timescales.

Stromboli is a perfect case study for U-series investigations due to its continuous and regular activity, which allow studying variations of the feeding system with an almost continuous time-resolution. Moreover, previous multidisciplinary studies on the plumbing system provide well established constraints to explore the full potentialities of U-series isotopes in volcanic systems.

Two different types of magma characterize the present-day activity of Stromboli. The LP magma, with low phenocryst content is erupted only during major explosions and paroxysms. It represents deep fresh magma input into the shallow magma chamber. The HP magma occurs during normal strombolian activity and lava flows. It shows low phenocryst content and, in general, it can be considered to derive from the LP magma through differentiation processes in the shallow magma chamber.

We analyzed the parent-daughter pairs 226Ra-230Th, 230Th-238U, as well as the activity ratios (230Th/232Th) and (238U/232Th) in HP and LP magmas ejected in the last 20 years. Few older samples from the last century were also analyzed for comparison.

The two magmas show similar but distinct composition for U-series isotopes. (238U/232Th) is slightly higher in HP (0.800-0.808) than in LP magma (0.785-0.795). (230Th/232Th) is the same in the two groups whereas (226Ra/230Th) is much lower in HP magmas (2.23-2.46 versus 2.51-2.66).

Variations in U/Th can't be explained by fractionation and/or assimilation of mineral phases since they must involve a component enriched in U and Th. This material represents the residue of an old magma recycled within the present-day shallow chamber. Most likely, this component shares a common origin and age (i.e. <2 ka) with the old crystals (antecrysts) described by previous works [e.g. Francalanci et al. 2012]. This process is also confirmed by the lower excess of (226Ra/230Th) since the disequilibrium decreases over time due to the aging. However, the correlation of (226Ra/230Th) with Ba/Th implies plagioclase fractionation in the HP magma. Such process must be extremely quick and in strong disequilibrium with the liquid in order to describe the similar partitioning of Ra and Ba into the plagioclase. Thus, the crystallization and fractionation of plagioclase probably occur during the final ascent of the magma towards the surface.

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The large and destructive 1669 AD eruption at Etna Volcano: reconstruction of the lava flow field evolution and effusion rate trend

Stefano Branca, Emanuela De Beni, Cristina Proietti

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy

The 1669 AD flank eruption was the most destructive event on Etna Volcano in historical times (700 BC). The 1669 lava was fed from a low-altitude vent, at about 800 m a.s.l. and close to the town of Nicolosi, covering 40x10^6 m2 in only four months. It is the widest and longest lava field (17 km) produced by Etna Volcano both in historical and in prehistoric times [Branca et al. 2011]. During its advance, the flow destroyed seven little towns and several other minor villages and partially damaged San Giovanni Galermo and the western portion of Catania. Volcano-tectonic earthquakes preceding the eruption almost completely destroyed Nicolosi and seriously damaged four townships. A violent explosive activity produced a large, 1 km wide and 200 m high, scoria cone (Mts. Rossi) and a thick, widespread pyroclastic fall deposit along the lower southeast flank of the volcano [Walker 1975]. The 1669 eruption produced a relatively wide 'a'a flow-field [Kilburn and Guest, 1993] that can be classified as compound [Walker 1971, 1973]. It is particularly important to evaluate its volume and reconstruct its temporal evolution because it represents the worst-case scenario for these events. The 1669 lava field is a unique case study to directly measure its thickness and reconstruct the temporal evolution of the average effusion rate.

Figure 1. Panoramic view of a quarry located in the branch that reached the town of Catania. In the background there is the Mt Rossi scoria cone, the main vent of the 1669 eruption.

A total of 138 thickness measurements were acquired, using both subaerial and subsurface data [Branca et al., submitted]. Subaerial thickness measurements were collected from exposures in 22 quarries as well as at 11 locations where the lava walls were exposed (see Figure 1). A Garmin GPS and a compass were used to determine the measurement locations. Thicknesses were evaluated, with a Leica Laser locator, only if the base and the top of the lava were clearly visible. Fifty-three subsurface measurements were obtained from 20 geognostic continuous cores, 3 wells and 30 working-faces of the new Catania underground. Thickness measurements acquired allowed dividing the lava field into 12 zones of homogenous mean thickness and obtaining a total lava volume of 607 x10^6 m3, corresponding to an average effusion rate of 70 m3/s. This new volume differs by -24% up to +64%, from previous published values. The temporal evolutions of the cumulative volume and average effusion rate were reconstructed for the first fourteen days, from field data and the analysis of historical records. A short initial phase was characterized by a rapid increase of the effusion rate, which reached a peak of ~640 m3/s after three days. This was followed by a longer phase in which the flow rate decreased. The first fourteen days were crucial for the development of the lava field that covered 72% of its final area and produced most of the damage. Thereafter, the growth of a complex lava tube network promoted lava field lengthening to the city of Catania. Effusion rate trends following the pattern of the 1669 eruption can be adopted for future investigations aimed at assessing the effects of similar events on Etna's highest urbanized area and at other effusive basaltic volcanoes.

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Vents Pattern Analysis at Mount Etna Volcano (Sicily)

Alfonso Brancato[1], Mauro Coltelli[2], Cristina Proietti[2], Giuseppina Tusa[2], Stefano Branca[2]

[1]*Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Catania, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*

Mt. Etna is the largest, as well as the most active volcano in the Mediterranean Sea. Volcanism started about 500 ky ago and the erupted magmas range from tholeitic to alkaline affinity. An almost continuous summit activity characterizes the volcano; however, flank eruptions occur at an interval of years, mostly concentrated along the NE, S and W rift zones.

A vent clustering at various scales is a common feature in many volcanic settings. In order to identify the clusters within the studied area, a spatial point pattern analysis is undertaken using known historical positions. It reveals both clustering and spatial regularity in the Etna region at different distances.

The visual inspection of the vent spatial distribution suggests a clustering on the rift zones of Etna Volcano. To confirm this evidence, a coarse analysis is performed by the application of X2 and t-test simple statistics. Then, a refined analysis is performed by using the Ripley's K-function, whose estimator K(d), knowing the area of the study region and the number of vents, allow us to calculate the distance d among two different location of events.

The above estimator can be easier transformed by using the L(d) function; the peaks of positive L(d) values indicate clustering and troughs of negative values stand for regularity for their corresponding distances d (L(d)=0 indicates complete spatial randomness).

In this study, spatial and temporal patterns of known vents are investigated in order to model the spatial distribution of likely eruptive vents for the next event, basically in terms of relative probabilities. For this, a Gaussian kernel technique is used. Moreover, the above L(d) function is adopted to generate an optimal smoothing bandwidth based on the clustering behaviour of the Etna Volcano.

New archeomagnetic and 226Ra-230Th dating of recent lavas allowed us to consider a detailed catalogue of flank eruptions at Mt. Etna, spanning the period 396 BC-2008 AD [Tanguy et al., 2012]. For our analysis, a total of 96 (Figure 1) well identified vents is used to model the spatial density for flank volcanism occurred during historical time. The investigated region covers an area of 792 km2, divided into 24×33 squared cells of size of 1 km by 1 km. In particular, the dataset generally considers one main vent for each eruptive event, but includes more than one vent only when more lava flows were contemporaneously emplaced on different volcano slopes (i.e. 2002-2003 eruption). The vents were generally located on the new geological map of Etna Volcano [Branca et al., 2011]. Some historical vents, which result covered presently, were extracted by the previous

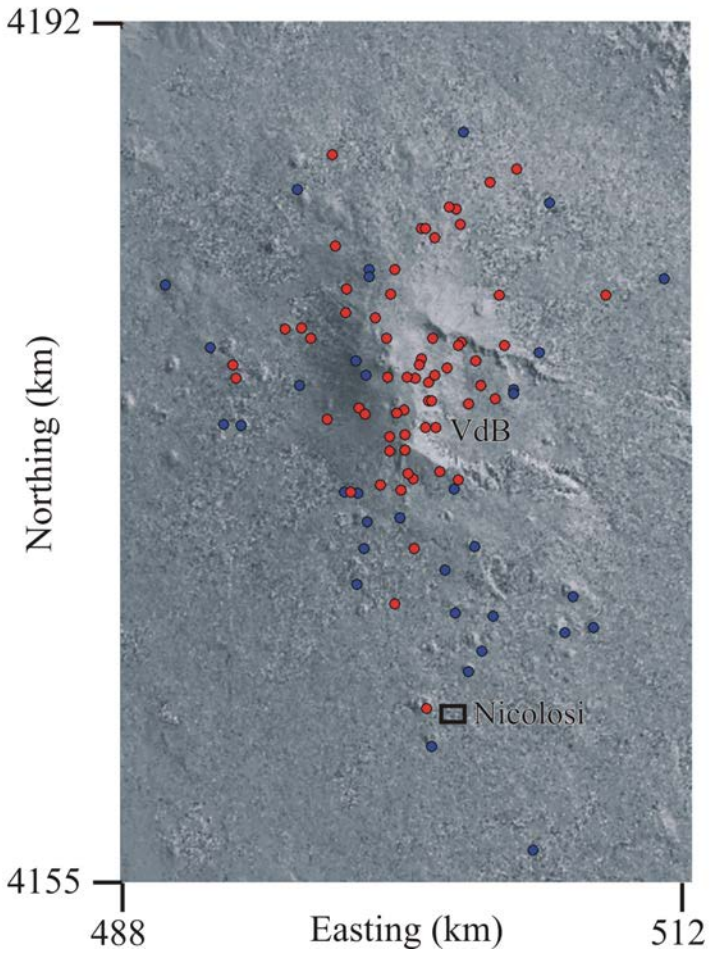

Figure 1. Spatial distribution of the historical vents for Etna volcano used in this study (blue dots indicate vents for eruptions occurred before 1600 AD; red dots indicate vents for eruptions occurred after 1600 AD). VdB=Valle del Bove.

geological maps; other vents, mostly related to eruptions occurred before 1600 AD, were located on the basis of the lava flow fields cropping out.

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A Bayesian Event Tree for eruption forecasting: An application at Mount Etna Volcano (Sicily)

Alfonso Brancato and Stefano Gresta

Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Catania, Italy

Volcanism at Mt. Etna, apart frequent summit activity, occurs, at an interval of years, from the flanks of the volcano, being mostly concentrated along the NE and S rift zones.

Because of Mt. Etna is located in a densely urbanized area, its flank eruptions must be managed for risk-based in decision-making in land-use planning and emergency. As a consequence, volcanic hazard must be managed with reliable probabilistic estimates of quantitative long-, mid- and short-term eruption forecasting, also by considering the large number of variables involved in a volcanic process.

Brancato et al. [2011, 2012] showed that this topic was successfully dealt with the application of the code named BET_EF (Bayesian Event Tree_Eruption Forecasting). It is based upon five subsequent nodes, whose first three (Unrest/No Unrest, Magma/No Magma, Eruption/No eruption, respectively) are mutually exclusive and exhaustive. Last two nodes deal with vent location and size/style of the eruptive event, respectively.

At an open-conduit volcano, anomalies in seismological, ground deformational, geochemical and volcanological monitoring parameters are determinant in providing the probabilistic estimate of the eruption occurrence, as well as of location of the relative vents. Therefore, an elicitation process fixed the monitoring dataset used to customize the software code for the Mt. Etna Volcano, with the consequent goal of producing an improved workflow between qualitative and quantitative information, even if new data are incoming. The implementation of all possible data into the statistical code and the relative outcomes can remove some of the apprehension that might go along with making subjective and/or false predictions.

The present application essentially revises the monitoring dataset used for the retrospective January 2001-April 2005 time period [Brancato et al., 2011], thus modifying the relative outputs. The volcanic tremor is a parameter effectively linked to the summit activity [see the case of the lava fountains preceding the 2001 July-August flank eruption; Brancato at al., 2011]. More, CO2 anomalies have produced a sequence of false predictions [Brancato et al., 2011] with long-lived times, probably induced by a wrong elicitation of the parameter. To avoid any bias in the estimation of the flank eruption outcomes, these parameters are not used anymore, thus yielding the monitoring dataset to 34 of collected data.

Microgravity anomalies were measured starting between February and May 2001. The relative evidence was not well supported in previous probability estimates [Brancato et al., 2011, 2012]; therefore, a revision of the thresholds of the gravity parameters was due.

For the present application, anomalies in seismicity, ground deformation, SO2 emission and gravity data were observed in a time period spanning from weeks to months in advance of the onset of the July-August 2001 and October 2002-January 2003 flank eruptions. As a consequence, eruption probabilities (node 3) higher than 90% were estimated for both events. Conversely, the flank eruption of September 2004-March 2005 was not heralded by significant anomalies (estimated probabilities around 30%).

The code application clearly showed the leading role of the monitoring data in estimating the principal phases usually involved in an eruptive state, primarily based on a clear identification of the thresholds of the acquired parameters. By the present time, they offer the best response, meanwhile providing an accurate improvement if new data from monitoring are incoming.

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Magma feeding an early hydromagmatic activity in the potassic period of Stromboli: the cases of the COA pyroclastic sequence and San Vincenzo scoria cone

Eleonora Braschi[1,2], Lorella Francalanci[1,2], Martijn Klaver[3], Gareth R. Davies[3]

[1]*CNR, Istituto di Geoscienze e Georisorse, sezione Firenze, Italy*
[2]*Universitá degli Studi di Firenze, Dipartimento di Scienze della Terra, Firenze, Italy*
[3]*Vrije Universiteit, Departement of Earth and Environmental Sciences, Amsterdam, Italy*

A hydromagmatic volcanoclastic sequence (Semaforo Nuovo succession), cropping out close to the Advanced Operations Center (COA) of the Department of Civil Defense [the so called "COA succession" of Porreca et al., 2006] has been until now attributed to the final activity of the Neostromboli period, nearly coeval with the eruption of the Secche di Lazzaro pyroclastic sequences [Bertagnini and Landi, 1996; SDL-S and SDL-N of Petrone et al., 2009]. The Semaforo Nuovo pyroclastic succession is an approximately 3-4 mt thick deposit made up of mostly thinly bedded to massive lapilli-tuffs with abundant accretionary lapilli deposited from mainly PDCs with variable clast concentration.

This sequence has been sampled in detail, collecting pumices from each stratigraphic layer for a total of about 10 samples. The juvenile fragments (scoriae and abundant quite small golden pumices) of the Semaforo Nuovo pyroclastic sequence have evolved high-K shoshonite compositions (K2O around 4.5 wt%, with silica of 53.5-55.2 wt%), with low MgO contents (2.3-3.0 wt%), which is the typical composition of the KS evolved rocks. In detail, pumices have composition slightly different than the grey scoria, suggesting slight zoning of magma reservoir. All the samples have a paragenesis characterized by plagioclase, clinopyroxene, olivine and opaques. Mineral chemistry analyses show quite variable composition for clinopyroxene (Mg# 0.68-0.87) and plagioclase An77-86, whereas olivine has slightly constant composition with Fo67-68.

The Semaforo Nuovo pyroclastic sequence directly overlies the deposits of the San Vincenzo scoria cone, formed in the area of the Stromboli village and representing a relatively recent eccentric vent, whose activity is dated back to 12.5 ka [Wijbrans et al., 2010]. It consist of a succession of welded to loose, strombolian fallout scoriae, lava spatter and flows and minor pumices emitted from a slightly NE-SW-elongated eruptive fissure [Calvari et al., 2010; Francalanci et al., in press). A total of 16 samples were taken on the scoria cone flank, from several new outcrops near the football pitch. All the samples show hypocrystalline groundmass and highly vesiculate, glomeroporphyritic textures with a paragenesis dominated by clinopyroxene, plagioclase, olivine and opaques [Klaver, 2008]. Compositional data show that both the San Vincenzo scoriae and lava flows are high-K shoshonites belonging to the evolved group of the KS rocks. They also reveal that the San Vincenzo products have a strict geochemical and isotopic similarity with the Semaforo Nuovo succession, thus the two deposits have been related to a unique period of mild explosive activity that took place during the early stages of the Neostromboli potassic activity. This study seems therefore to validate the existence of an evolved hydromagmatic explosive phase during the effusive potassic period and not only at the end of the period.

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The origin of plagioclase macro-phenocrysts in the post-caldera lavas of Nysyros Volcano (Greece): Micro-Sr Isotope evidences

Eleonora Braschi[1], Lorella Francalanci[1,2], George E. Vougioukalakis[3], Simone Tommasini[2]

[1]CNR, Istituto di Geoscienze e Georisorse, Sezione Firenze, Italy
[2]Universitá degli Studi di Firenze, Dipartimento di Scienze della Terra, Firenze, Italy
[3]I.G.M.E., Aharnes, Athens, Greece

We present the result of a detailed study based on in-situ Sr-isotopes determinations, associated with mineral chemistry investigations, resolving the provenance of plagioclase macro-phenocrysts hosted both inside evolved dome-lavas and their mafic enclaves of the last magmatic activity of Nisyros Volcano (South Aegean Active Volcanic Arc, Greece).

Nisyros Volcano is characterized by a recent (<24 ky) post-caldera activity emplacing six rhyo-dacite domes after a Plinian eruption (Upper Pumice eruption), triggering the caldera collapse. Domes are characterized by the presence of mafic (basaltic-andesite) magmatic enclaves that mingled with the evolved host and were extruded together, inside and outside the caldera depression. Mingling processes also develop at the micro-scale, involving crystal and groundmass portions with widespread exchanges between domes and enclaves components.

Dome-lavas are porphyritic with a paragenesis dominated by plagioclase, present mostly as large crystals (0.5-5 mm) with low-An contents (An25-35). Mafic enclaves show dictitaxitic groundmasses and quite porphyritic texture, characterized mostly by plagioclase phenocrysts showing similar size, textures and composition than those of the host rhyo-dacite. Plagioclases are also present as groundmass microlites, having more anhortitic composition (An75-85). Among the enclaves, plagioclases show a bimodal composition reflecting their different origin and history of crystallization.

Micro-sampling have been performed by MicroMill™ device and measurements by Triton-Ti spectrometer at the Department of Earth Sciences of Florence. Our results show that, among all the micro-drilled plagioclases, the 87Sr/86Sr is well negatively correlated with the An content. Low-An cores show quite homogeneous 87Sr/86Sr, ranging from 0.7044 to 0.70452, well above the isotopic signature of their hosts and comparable to the isotope values of the Upper Pumice juvenile. Rims (An55-75) have clearly lower, more scattered 87Sr/86Sr (0.70415- 0.70398) that are similar to those of the dome-lavas whole-rock.

Our data verify that most of the macro-plagioclases are xenocrysts in respect to the enclave magma and comes from the host rhyo-dacitic magma by ingression when enclaves are steel molten. Further, they reveal that macro-phenocrysts probably crystallize from the previous Upper Pumice magmatic system, being antecrysts in respect with the studied systems.

We demonstrate that the Upper Pumice represents the parental system from which the post-caldera products evolved. Our data can be also interpreted as the evidence of a long history of crystallization for macro-plagioclase, that are involved in recycling processes from Upper Pumice to post-caldera dome system. The presence of thin equilibration rims also indicate rather low time of interaction between basaltic-andesite and rhyo-dacite magmas before the dome emplacement.

The clean-up of the Pizzi Deneri area

Salvo Caffo[1], Massimo Cantarero[2], Giuseppe Falzone[2], Carmelo Ferlito[3], Ferruccio Ferrari[2], Angelo Ferro[2], Salvatore Gambino[2], Giuseppe Laudani[2], Giuseppe Puglisi[2]

[1]*Ente Parco dell'Etna, Nicolosi, Catania, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[3]*Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Catania, Italy*

The clean-up of the territory consists of interventions aimed at reclaiming and rehabilitating a degraded area. The problem of recovering areas in a state of neglect and/or affected by the presence of illegal landfills and abandoned former quarries is a growing and current issue, which also concerns mountain areas. The main example of such a situation is Mt. Everest, which is full of waste due to an increasing number of expeditions that do not break down owing to the low temperatures. In Italy, there are a number of situations regarding abandoned concrete structures, removed soils, rusted pylons and ghost chair lifts, such as at Valcanale (Bergamo) or at the Cinisello lakes (Parco Naturale Adamello Brenta).

Mt. Etna is one of the world's most active and monitored volcanoes, also representing one of the main tourism destinations in Sicily.

The INGV-OE (in the past IIV-CNR, Sistema Poseidon) carries out its research and monitoring activities on Mt. Etna by using several measurement systems located on the territory. Scientific (and non-scientific), as well as private institutions have installed in the last 30-40 years a large number of remote stations, consisting of concrete/metal housing structures equipped with solar panels and antennas set up on the edifice flanks, particularly concentrated in summit area. Some of these structures have been destroyed and/or entirely abandoned today.

In order to grant permission for the development of the INGV permanent tilt network, the CTS (Comitato Tecnico Scientifico) inside the "Ente Parco dell'Etna" have agreed to liberate an area between the Pizzi Deneri Observatory and Rocca Della Valle from the numerous abandoned technological wastes.

In this poster, we report the details of this intervention and a photographic survey made before and after the clean-up.

Rain-ash interaction during paroxysmal events as potential input of toxic trace element in the environment: example from Mt. Etna Volcano

Sergio Calabrese[1], Walter D'Alessandro[2], Francesco Parello[1]

[1]*Università di Palermo, Dipartimento Scienze della Terra e del Mare, Palermo, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy*

Volcanic emissions represent one of the most relevant natural sources of trace elements to the troposphere, both during and between eruptions. Due to their potential toxicity they may have important environmental impacts from the local to the global scale.

Mount Etna, the largest European volcano and one of the most active volcano in the world, covers an area of about 1250 km2 and reaches an altitude of about 3340 m. It has been persistently active during historical time, with frequent paroxysmal episodes separated by passive degassing periods. Atmospheric precipitation was collected approximately every two weeks, from April 2006 to December 2007, using a network of five rain gauges, located at various altitudes on the upper flanks around the summit craters of Etna Volcano. The collected samples were analysed for major (Ca, Mg, K, Na, F, SO4, Cl, NO3) and a large suite of trace elements (Ag, Al, As, Au, B, Ba, Be, Bi, Cd, Co, Cr, Cs, Cu, Fe, Hg, La, Li, Mn, Mo, Ni, Pb, Rb, Si, Sb, Sc, Se, Sr, Th, Ti, Tl, U, V, Zn) by using different techniques (IC, SPEC, ICP-MS and CV-AFS). The monitoring of atmospheric deposition gave the opportunity to occasionally sample volcanic fresh ashes emitted by the volcano during the paroxysmal events. This was possible because the network of five rain gauges were equipped with a filter-system to block the coarse material. In this way, more than twenty events of ashfall were collected. Unfortunately, only half of these samples were suitable for a complete chemical analysis, because of the small amount of sample. In order to obtain elemental chemical composition of ashes, powdered samples were analysed by a combination of methods, including X-ray Fluorescence Spectroscopy (XRF), total digestion followed by Inductively Coupled Plasma Emission Mass Spectrometry (ICP-MS), Instrumental Neutron Activation Analysis (INAA), and infrared detection (IR).

The chemistry of rainwater reveals that most of the investigated elements have higher concentrations close to the emission vent of the volcano, confirming the prevailing volcanic contribution. Rainwater composition clearly reflects the volcanic plume input. Ash-normalised rainwater composition indicates a contrasting behaviour between volatile elements, which are highly-enriched in rainwater, and refractory elements, which have low rainwater/ash concentration ratios. The degree of interaction between collected ash and rainwater was variable, depending on several factors: (i) the length of the period in which tephra was present in the sampler (the ash fall may have occurred any day from the first to the last day of the rain collecting period); (ii) the amount of rainwater fallen on the collectors after the ash-fall event, and its acidity; (iii) the granulometry of the ash samples that was widely variable (from few centimetres to micrometric particles) increasing the interaction with decreasing dimensions of the grains; (iv) the distance of collector with respect to the craters. In order to investigate the role of volcanic ash on the evolution of the rainwater chemistry, absolute concentrations of rain and ash were plotted in binary plot diagrams (Figure 1). Each diagram corresponds to a single event, and pH and TDS of the solution collected is reported. The diagonal bars in the diagrams represent the rain/ash ratios (1:1 and 1:10000).

The results confirm that sulphate and halide salt aerosols are adsorbed onto ash particles, and their rate of dissolution in rainwater depends on solubility. Moreover, rapid chemical weathering of the silicate glass by volcanic acid (SO2, HCl and HF) can also explain the enrichment of several refractory elements (Na, K, Ca, Mg, Si, Al, Fe, Ti, Sc). Our observations highlight how explosive activity can increase enormously the deposition rate of several chemical elements, up to several km away from the emission vents.

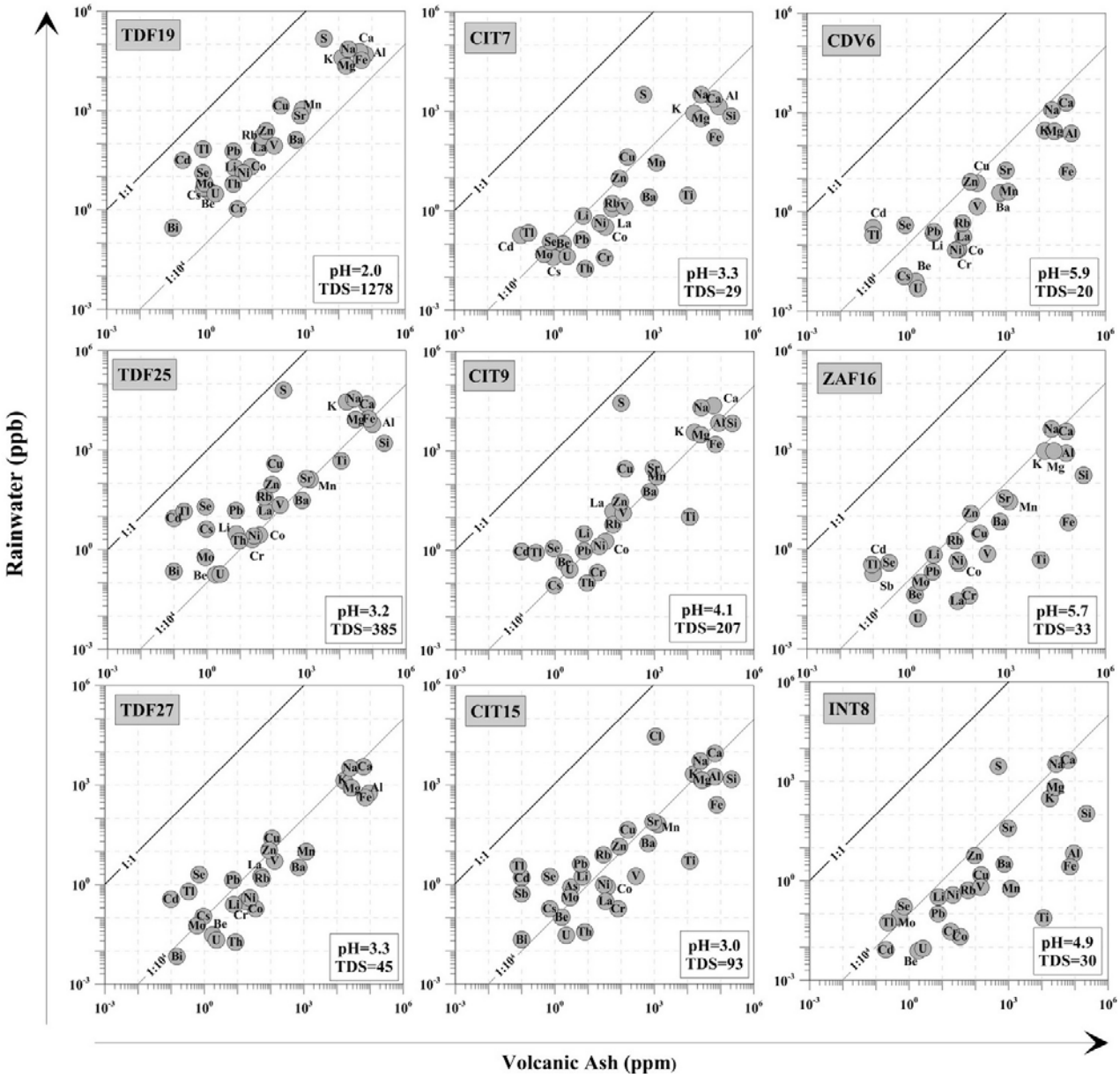

Figure 1. Rainwater and volcanic ash concentrations for nine different ash emission events. Total dissolved solid (TDS) are expressed as mg/l.

A literature review and new data of trace metals fluxes from worldwide active volcanoes

Sergio Calabrese[1], Sarah Scaglione[1], Walter D'Alessandro[2], Lorenzo Brusca[2], Sergio Bellomo[2], Francesco Parello[1]

[1]*Università di Palermo, Dipartimento Scienze della Terra e del Mare, Palermo, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy*

Volcanic emissions are considered one of the major natural sources of several trace metals (e.g. As, Cd, Cu, Pb, and Zn) to the atmosphere [Nriagu, 1989], and the geochemical cycles of these elements have to be considered strongly influenced by volcanic input. However, the accurate estimation of the global volcanic emissions of volatile trace metals into the atmosphere is still affected by a high level of uncertainty. The latter depends on the large variability in the emission of the different volcanoes, and on their changing stage of activity. Moreover, only few of the potential sources in the world have been directly measured [Hinkley et al. 1999]. Atmospheric deposition processes (wet and dry) are the pathways through which volcanic emissions return to the ground (soils, plants, aquifers), resulting in both harmful and beneficial effects [Baxter et al. 1982; Aiuppa et al. 2000; Brusca et al. 2001; Delmelle, 2003; Bellomo et al. 2007; Martin et al. 2009; Floor et al. 2011; Calabrese et al. 2011].

In the first part of this study we present the results of a literature review on trace metals emissions from active volcanoes around the world. In the second part, we present new data on the fluxes of the trace metals from Etna (Italy) and four active volcanoes in the world: Turrialba (Costarica), Nyiragongo (DRC), Mutnovsky and Gorely (Kamchatka).

We found 27 publications (the first dating back to the 70's), 13 of which relate to the Etna and the other include some of the world's most active volcanoes: Mt. St. Helens, Erebus, Merapi, White Island, Kilauea, Popocatepetl, Galeras, Indonesian arc, Satasuma and Masaya. The review shows that currently there are very few data available, and that the most studied volcano is Mt. Etna. Using these data, we defined a range of fluxes for As, Ba, Bi, Cd, Cu, Fe, Mn, Pb, Se, V and Zn (Figure 1).

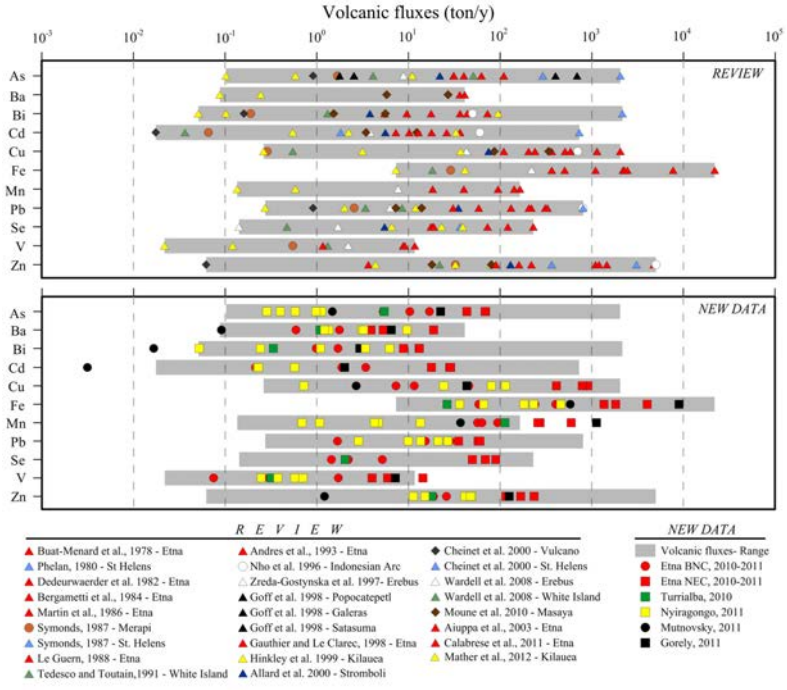

Figure 1. Volcanic fluxes of selected trace elements from active volcanoes. In the upper part data from the literature review; in the lower part new data from our study (Etna, Turrialba, Nyiragongo, Mutnovsky and Gorely).

To obtain new data we sampled particulate filters at the five above mentioned volcanoes. Filters were mineralized (acid digestion) and analyzed by ICP-MS. Sulphur to trace element ratios were related to sulphur fluxes to indirectly estimate trace elements fluxes. Etna confirms to be one of the greatest point sources in the world. The Nyiragongo results to be also a significant source of metals to the atmosphere, especially considering its persistent state of degassing from the lava lake. Also Turrialba and Gorely have high emission rates of trace metals considering the global range. Only Mutnovsky Volcano show values which are sometimes lower than the range obtained from the review, consistent with the fact that it is mainly a fumarolic field.

This work highlights the need to expand the current dataset including many other active volcanoes for a better constraint of global trace metal fluxes from active volcanoes.

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Explosive mafic eruptions: the fall-out phase of the "Pozzolane Nere Fm." (Colli Albani Volcanic District, Rome)

Silvia Campagnola, Claudia Romano, Guido Giordano, Alessandro Vona, Danilo Di Genova

Università degli Studi Roma Tre, Dipartimento di Scienze Geologiche, Roma, Italy

Colli Albani (Roma) is a composite quaternary volcano that became active at approximately 600 ka and that is now considered to be in a quiescent state. Both explosive and effusive products are remarkably undersaturated and belong to the HK-Series. In spite of its very silica poor compositions, the volcano displays features identical to those of felsic volcanoes, like low aspect ratio ignimbrites, tens of cubic kilometres large, and a related central (8x8 km) collapse caldera.

Despite the widespread literature about the structure and history of the volcano, the mechanisms governing the explosive activity of these very undersaturared magmas are still unknown.

In order to improve our understanding on the origin of these high-energy eruption, we carried out a detailed investigation of one of the largest explosive events in the history of the volcano (407 ka, Vulcano Laziale phase), the Pozzolane nere formation (PNR).

The PNR formation is characterized by a basal scoria fall deposit showing an east-trending axis of dispersion and a maximum thickness of about 2 meters overlain by a widespread low aspect ratio ignimbrite, estimated at 30km3 as bulk volume. In this study, we analyse in detail the textural characteristics and physical properties of the scoriaceous PNR basal fall-out deposit. For our investigation, we have chosen two different sites: i) Artena, i.e. a proximal deposit situated along the maximum axis of dispersion and ii) Tivoli, i.e. a distal deposit situated north-east with respect to the eruption centre. In each level, 50 scoria clasts have been selected to determine density and vesicularity by He picnometer. Petrological and minero-chemical analyses of the samples were performed by a combination of SEM and microprobe techniques. We analysed the internal textures and structure of the scoria clasts in order to assess the role of vesicles and microlites in eruptive style and history of the eruption. Results from the vesicle size distribution of the selected scoriae suggest an uneven distribution of nucleation events. Various clasts types have been recognized with different history of nucleation and growth processes. Bubble Number Densities (BNDs) vary from 10^6 at the bottom of the deposit, similar to those known for violent strombolian eruptions, to 10^5 in the middle, returning to 10^6 at the top, and up to10^7 in the overlying ignimbrite, indicating that the eruption was increasing in energy. Crystal fraction of the scoriae sample is about phi=0.10 with leucite microphenocrysts (>50 microns) and leucite + clinopyroxenes "microlites" (<20 microns).

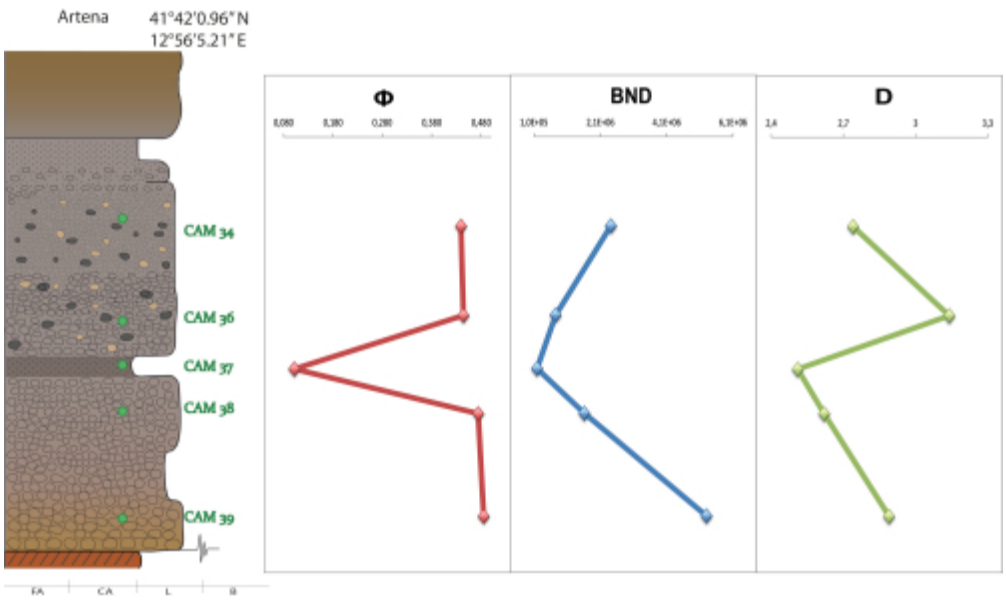

Figure 1. Stratigraphic column of the PNR fall-out with a synthetic scheme showing the main changes in the eruption dynamics: PHI indicates porosity, BND the Bubble number density and D the fractal dimension of size distributions.

Textural and minero-chemical investigations of the samples have been combined with their rheological characterization, in order to model the magma dynamics leading to the high-energy eruption of PNR. Pure liquid anhydrous viscosity of the remelted PNR fall-out at high (1124°C<T<1569°C) and low T (690°C<T<800°C) was performed by a combination of concentric cylinder measurements and micropenetration technique. Multiphase rheology was computed through the Vona et al. model for crystal bearing magmas both for the fall out and the PNR flow.

Repeating volcano-tectonic earthquakes at Mt. Etna Volcano (Sicily, Italy): characterization and evidences of crustal changes

Andrea Cannata, Salvatore Alparone, Andrea Ursino

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy

Repeating volcano-tectonic (VT) earthquakes, taking place at Mt. Etna during 1999-2009, were detected and analyzed to investigate their behavior. We found 735 families amounting to 2479 VT earthquakes, representing ~38% of all the analyzed VT earthquakes. The number of VT earthquakes making up the families ranges from 2 to 23. Over 70% of the families comprise 2 or 3 VT earthquakes and only 20 families by more than 10 events. The occurrence lifetime is also highly variable ranging from some minutes to ten years. In particular, more than half of the families have a lifetime shorter than 0.5 day and only ~10% longer than 1 year. On the basis of these results, most of the detected families were considered "burst-type", i.e., show swarm-like occurrence, and hence their origin cannot be explained by a temporally constant tectonic loading. Indeed, since the analyzed earthquakes take place in a volcanic area, the rocks are affected not only by tectonic stresses related to the fairly steady regional stress field but also by local stresses, caused by the volcano, such as magma batch intrusions/movements and gravitational loading. We focused on five groups of families characterized by the best repeatability over time, namely high number of events and long lifetime, located in the north-eastern, eastern and southern flanks of the volcano. Unlike the first four groups, which similarly to most of the detected families show swarm-like VT occurrences, group "v", located in the north-eastern sector, exhibits a more "tectonic" behavior with the events making up such a group spread over almost the entire analyzed period. It is clear how both occurrence and slip rates do not remain constant but vary over time, and such changes are time-related to the occurrence of the 2002-2003 eruption.

We searched for waveform variations in VT earthquakes belonging to the group "v" and found changes that took place mainly in the 2002-2003 period. These consisted in a decreasing similarity of the late seismogram windows, highlighted by cross correlation analysis, as well as in delays, increasing proportionally to lapse time, detected by coda wave interferometry. Such variations, mainly evident at the stations located in the north-eastern flank of volcano, were likely due to medium changes taking place in this region. In particular, medium velocity decreases were inferred to occur in 2002-2003, followed by successive increases. The velocity decrease was interpreted as being caused by the opening or enlargement of cracks, produced by intruding magma bodies, ground intense deformation and/or VT earthquake activity, accompanying the 2002-2003 Mt. Etna eruption. On the other hand, the subsequent velocity increases were interpreted as resulting from healing processes.

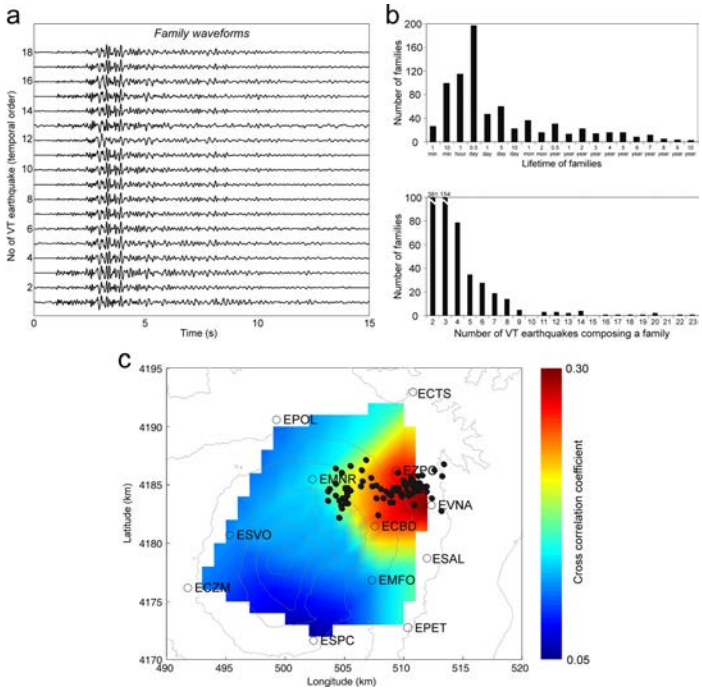

Figure 1. (a) Waveforms of VTs making up a family. (b) Histogram of number of families with a given lifetime and earthquake number. (c) Distribution of the difference between the cross correlation calculated between the early and the late seismogram windows.

Stratigraphical and volcanological aspects of the pyroclastic level of Amantea Basin (Coastal Chain, north-western Calabria)

Chiara B. Cannata, Rosanna De Rosa, Marcella Davì, Paola Donato, Francesco Muto

Università della Calabria, Dipartimento di Scienze della Terra, Arcavacata di Rende, Italy

The volcanic level object of this study has been recognized within the sedimentary infill of the Amantea basin. The Amantea basin is one of many Neogene basins along the Tyrrhenian margin of Calabria [Di Nocera et., 1974; Ortolani et al., 1979; Colella, 1995; Mattei et al., 1999]. The sedimentary infill of the basin is characterized by five main depositional units bounded by stratigraphic disconuities [Muto & Perri, 2002]. The onset of the basin started during the early Tortonian, in response to tectonic subsidence induced by extensional faulting. The first unit shows a time-transgressive sedimentary evolution for the basin, with facies associations varying from alluvial fan to submarine fan deltas. In the second unit an alluvial fan overlain by a carbonate platform depositional system are present. It overlies the first unit with an angular unconformity, due to the fall of the sea level and synsedimentary activity of normal faults. During the deposition of the upper part of the second unit (late Tortonian), the basin was subjected to contractional deformation. It strongly influenced the development of the sedimentary sequence, producing numerous unconformities in response to the growth of anticlinal folds. In this time period a new rise of sea level occurred. It caused transgression over adjacent continental zones. The third unit records these phenomenas. Local emergence of basin-fill produced intrabasinal sediments and the deposition of coarse-grained fan at the base of the unit. A successive drop of the sea level brought to the development of a thin evaporitic succession which characterizes the fourth unit. It starts with an angular unconformity on sediments and bedrock dated back to late Messinian. The fifth unit is characterized by marine sediments lying at varied topographic levels, testifying the uplift of the basin that continued through the Pleistocene. The last deformation phase was characterized by extensional fault systems, dipping toward Tyrrhenian Sea, ending the basin emergence. The volcanic level object of this study has been recognized within the first depositional unit of nineteen outcrops. The first unit was dated back by Mattei et al. [2002] to Serravallian age. Field observations and also petrographic and geochemical analyses revealed that the pyroclastites belong to a sub-areal, explosive volcanism of rhyolitic composition, which suffered a primary transport via aereal or flows. On the field, the volcaniclastic level shows centimeter thick-plane parallel layers, light brownish to dark grey, yellow or deep yellow, with grain size varying from silt to coarse-grained sand. On the top the raising of thickness is associated with a decreasing of the grainsize of deposit. Coarser layers are massive or bended, while the thinner are laminate bended. Each flow unit of the deposit shows a clear gradation with rhythmic alternation which is associated to sedimentary structures. It gives inferences for a turbidity current origin. Therefore we propose the idea that the volcaniclastic level of Amantea Basin takes origin from secondary sedimentation by turbiditic flows, mixing with sedimentary silicoclastic materials in marine environments. The age of the depositional level in which we found the pyroclastic level and the rhyolitic composition of the last suggest that the provenance of volcaniclastic grains could be associated to the late stadies of Sardinian magmatic activity, in respect to other rhyolitic pyroclastites of the western mediterrean area.

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Tide gauge network of the Neapolitan volcanic area: 14 years of observations

Paolo Capuano[1], Francesco Obrizzo[2], Umberto Tammaro[2],
Adriano La Rocca[2], Salvatore Pinto[2], Enrico Vertechi[2]

[1]*Università di Salerno, Dipartimento di Fisica, Fisciano (SA), Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Italy*

The tide gauge network of Neapolitan volcanic area consists of nine stations (Figure 1): three in the Gulf of Naples, four in the Gulf of Pozzuoli, one in the Gulf of Salerno and one at Ischia island (La Rocca et al, 2005; Obrizzo et al, 2009). All stations are equipped with digital sensor and sampling rate between 5 and 1 minute.

Analogue data since 1999 and successively digital data have been retrieved and a database have been organized, corrected and validated up today, spanning over 14 years, using where necessary statistical gap filling technique. Data have been analyzed in the frequency domain and the local astronomical components have been defined by harmonic analysis, inferring amplitude and phase for the main diurnal and semi-diurnal components. Detrending the sea level respect to the astronomical tide, we obtain a signal which contains two terms: sea level background and local sea level variations due to site effects [Capuano et al., 2004a,b], noise and ground deformation [Obrizzo et al, 2009; Tammaro et al., 2009]. The deconvolution of the signal at each site respect to the reference station (NAPT, located in the harbour of Naples) provide an estimation of ground level variation .

The results show no significant level variation at Vesuvian area, while, in the Campi Flegrei caldera, tide gauge network have detected the so-called mini-uplift episodes occurred in the last decades. In particular, the tide gauge in Pozzuoli harbour (POPT, Figure 1) shows, from 2004 to 2012 (September) a cumulative uplift reaching about 14 cm.

Using 14 years of measurements, we have assessed a preliminary estimation of the mean sea level (MSL) measured at Naples tide gauge, as local relative MLS trend. Tide gauge measurements are made with respect to a local fixed reference level on land.

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Continuous gravity observations tracks dynamic processes at Kilauea Volcano

Daniele Carbone[1], Michael P. Poland[2]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*Hawaiian Volcano Observatory, U.S. Geological Survey, Hawaii National Park, HI, USA*

Since May 2010, two continuously recording gravimeters have been operating at the summit of Kilauea Volcano, Hawai`i, 2 km and 150 meters from the summit eruptive vent, respectively. The purpose of the deployment is to detect rapidly evolving mass changes due to volcanic activity.

An analysis of the data acquired in May 2010 from both instruments reveals oscillations with period of about 150s. Source modeling suggests that the oscillations are caused by density inversions in a magma reservoir located about 1 km beneath the east margin of Halema'uma'u Crater in Kilauea caldera, a location of known magma storage. This result may represent rare geophysical evidence of convection in a shallow magma chamber. Continuous microgravity measurements may therefore provide a geophysical method for detecting and characterizing magma convection in subsurface reservoirs, which previously has only been inferred indirectly from geochemical observations.

Gravity variations have also accompanied changes in lava level within the summit eruptive vent. Indeed, the signal from the gravimeter closest to the active vent shows increases and decreases in gravity during lava level rise and drop, respectively, of a few microGals, implying small mass changes during the rise/fall cycles. Webcam images allow for comparison between gravity and lava level changes, providing an opportunity to constrain the density of the fluid beneath the lava crust. A strong gravity decrease of about 150 microgals occurred on 5 March 2011, when magma drained from the summit eruptive vent and shallow storage reservoir to feed a fissure eruption along Kilauea's east rift zone.

These observations demonstrate the ability of continuous gravity measurements to offer insights into volcanic activity that is difficult or impossible to infer from other datasets.

Magma emplacement below active calderas: the case of Ischia Island and Campi Flegrei (Southern Italy)

Stefano Carlino, Renato Somma, Claudia Troise, Giuseppe De Natale

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano

Campi Flegrei and Ischia Island are two active calderas, located in the Gulf of Naples, which have undergone to uplift and subsidence processes subsequent to ignimbrite forming eruptions (Figure 1).

The Campi Flegrei caldera is roughly 12 km wide, with its centre located in the Bay of Pozzuoli, about 15 km to the west of Naples. The current caldera shape is the result of two large collapses, the first of which was probably related to the Campanian Ignimbrite (CI; 150– 200 km3 DRE; age, 39 ky BP) and the second to the Neapolitan Yellow Tuff (NYT; 40 km3 DRE; age, 12–15.6 ky BP) eruptions.

Since at least 10 ka the caldera has been characterized by low subsidence, at a rate of about 1.1 to 2 cm y-1 interrupted by recurring phases of rapid uplift of caldera floor, with the most uplifted zone located in Pozzuoli as testified by the marine deposits outcropping about 40 a.s.l. (La Starza marine terrace, in Pozzuoli). The study of sea-level markers on Roman coastal ruins has also revealed historical ground movements, since 2000 years ago. Several phases of uplift have been recognized to have occurred in the Middle Ages, prior to the Monte Nuovo eruption (AD 1538; 0.02 km3 DRE). More recently, two phases of uplift have occurred, during 1970–1972 and 1982–1984, when the town of Pozzuoli was raised by 1.7 and 1.8 m, respectively. During the 1982–1984 unrest episodes, more than 15,000 shallow earthquakes (at 1–5 km in depth) with a maximum magnitude of 4.0 were recorded by the seismic stations of the Osservatorio Vesuviano), and the ground uplift occurred at an average rate of 0.3 cm d-1. The last episode of unrest indicated the possibility of an imminent eruption, forcing the authorities to evacuate Pozzuoli; however, the unrest essentially ended in December 1984, without any eruption occurring.

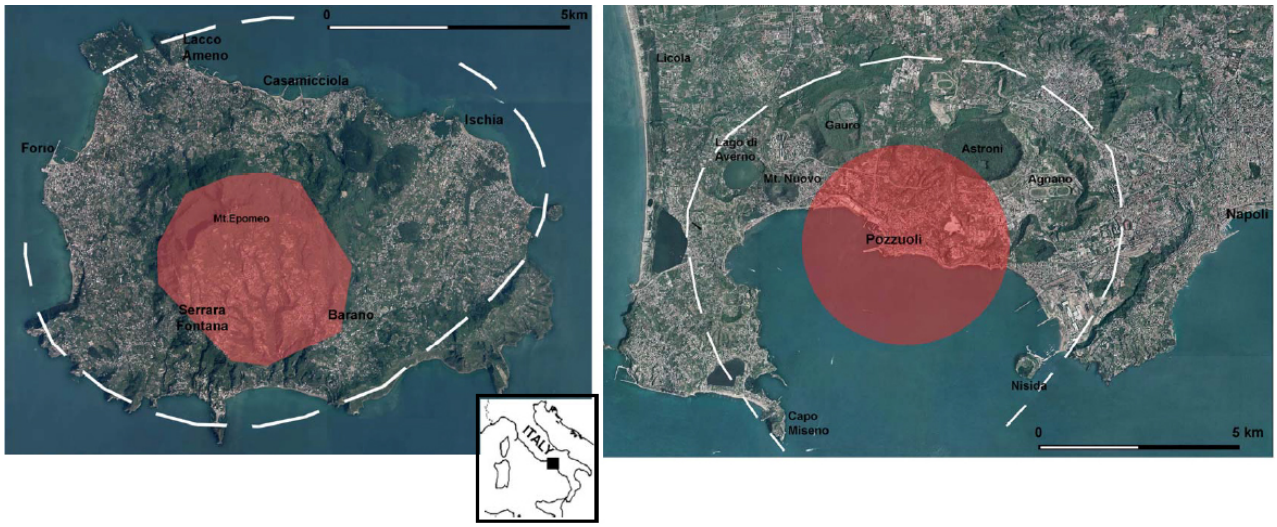

Figure 1. Ischia Island (left) and Campi Flegrei caldera (rigth). The dotted lines represent the caldera rims. The shaded red areas are those subjected to maximum deformation during the resurgence process.

Ischia Island is a 46 km2 volcanic field that emerges at the western edge of the Bay of Naples, consisting of rocks that are derived from a number of explosive and effusive eruptions that date back to about 150,000 years, with the most recent occurring in 1301–1302 AD. Since 55 ka, Ischia Island has undergone resurgence within a caldera that was formed after a great ignimbrite eruption (Mount Epomeo Green Tuff, 55 ka).

The total uplift deduced from the present height of the marine deposits and eustatic variations is 710 m in the southern sector and 920–970 m in the northern sector, with uplift ranging from 2.3 to 3.3 cm a^{-1}. The main active area that is involved in the resurgence is the block of Mount Epomeo, which is located in the

central sector of Ischia Island, with an area of roughly 4×4 km2. The edges of this block are marked by a system of sub-vertical faults with NW–SE, NE–SW, and N–S strikes. Archeological findings below the present sea level also show that Ischia Island has been undergoing subsidence over the past 2,000 years. It cannot be ruled out that this subsidence period has been punctuated by quick inversion phases of the ground movement, as occurred in the neighboring Campi Flegrei caldera over the last 26 years. The subsidence rate of Ischia Island since 1913 has been estimated at 1–5 mm a^{-1}. Nowadays, about 62,000 people live on Ischia Island and 350,000 at Campi Flegrei caldera, with consequent high volcanic risk.

Studies of the unrest mechanism and caldera dynamics using different physical approaches are useful to provide assessments of the volcanic risks of this densely populate area. The key issue related to unrest is the study of the physical conditions necessary to trigger an eruption. This is correlated to the depth and volume of magma chamber, rheology of the rocks around magma chamber and to the causative deformation processes at depth (magma, hydrothermal fluids, or a combination of both).

The main difference between Ischia Island caldera and Campi Flegrei caldera dynamic is represented by the amount of uplift, which is at least one order of magnitude larger at Ischia Island.

In this study two models proposed for the resurgent processes of these two calderas are showed, which are substantially different. At regional scale the volcanism of both areas can be related to the tensile tectonic of the area, which allowed the migration of almost certainly large magmatic source at a depth of 8-10 km and the rising of the Moho at about 20km. The model of Campi Flegrei caldera is related to fluid dynamics of hydrothermal system coupled with magmatic input, although the presence of shallow magma source is still under debate. On the contrary, the Ischia Island model shows that the dynamic of this area is likely associated to the laccolith emplacement at shallow depth (about 2 km). Both models can explain the behavior of these volcanic areas in terms of dynamics (uplift and subsidence), eruption occurrence and thermal state of the shallow crust.

Residence time analysis of active volcanic systems: the case study of Ischia and Pantelleria

Martina Casalini, Riccardo Avanzinelli, Simone Tommasini

Università degli Studi di Firenze, Dipartimento di Scienze della Terra, Firenze, Italy

Numerous active and potentially high-risk volcanoes do occur in the Italian peninsula (e.g. Aeolian islands, Vesuvio etc.) and therefore understanding their dynamics is crucial for volcanic hazard assessment. Here we present a study on the active volcanic systems of Ischia and Pantelleria, representing two high-silica volcanoes emplaced in subduction related and within-plate geodynamic settings, respectively.

The volcanic history of Ischia, started more than 150 ka and proceded until 1302 AD, is characterized by monogenic lava domes, pyroclastic and lava flows with composition from trachy-basaltic, trachytic,alkali-trachytic to phonolitic and latitic. Green-Tuff of Mount Epomeo represents an important level which evidences the occurrence of a catastrophic eruption.

Pantelleria, the largest Italian volcanic island, is located in the middle of the spreading Sicily Channel within-plate rift. This magmatic system, active at least for the last 150 ka, shows a clear volcanic cyclicity with periods of quiescence followed by emplacement of peralkaline rhyolites and trachytes in the form of lava flows and ignimbrites. Pantelleria is characterized by bimodal volcanism with the lack of intermediate products between mafic (alkali basalts and hawaiites) and differentiated products (trachytes and pantellerites).

The geochemical and radiogenic isotope data of the volcanic products of Ischia demonstrate a two-step evolutive process: the first step was controlled by fractional crystallization plus crustal assimilation (AFC) and drove magma composition from "basalt" to least differentiated trachyte; the second step was controlled only by fractional crystallization (FC), driving the magma composition to the more differentiated products (trachyte-phonolite), and determined very low Sr (a few ppm) and high of Rb (>500 ppm) content due to extreme plagioclase and K-feldspar fractionation. A number of evolved volcanic rocks from Ischia (i.e. low Sr and high Rb content) have anomalously high Sr isotope composition ($^{87}Sr/^{86}Sr>0.7075$), which cannot be justified by the assimilation of crustal material during the first step evolutive process and demand for other explanations.

The relationship between mafic and felsic products at Pantelleria has been explained alternatively with extensive FC processes from basalt to pantellerites or remelting of gabbroic bodies producing the trachytic magmas, which in turn differentiated to pantellerites by fractional crystallization.

The active volcanic systems of Ischia and Pantelleria, although belonging to different geodynamic settings, are characterized by the occurrence of strongly differentiated products with high Rb/Sr and anomalous high Sr isotope compositions. This characteristic could be explained by ^{87}Sr in-growth in long-lived magma chambers. To explore this hypothesis we carefully screened a number of evolved samples from Ischia and Pantelleria, on which we separated their rock-forming minerals (sanidine and clinopyroxene) and glass to determine Rb and Sr content by isotope dilution, along with Sr isotopic composition. The extremely low diffusion coefficients of Sr in feldspar and clinopyroxene makes them perfect candidates to estimate the timing of crystallization and, by inference, the magma residence time.

The obtained Rb-Sr mineral-glass ages are older than K-Ar eruption ages, allowing the determination of the magma residence time following sanidine and clinopyroxene crystallization. These estimates, representing minimum ages, yield magma residence times of some 70 ka and 30-40 ka for Pantelleria and Ischia, respectively, with the exception of one sample from Ischia yielding much higher magma residence time of some 800 ka before eruption. The results imply evolved magma storage at high temperature in closed and thermally insulated portions of the magma chamber and demand for a continuous heat supply from the feeding system of both Ischia and Pantelleria.

Motif discovery on seismic amplitude time series

Carmelo Cassisi[1], Marco Aliotta[2], Andrea Cannata[2], Placido Montalto[2], Domenico Patanè[2], Alfredo Pulvirenti[1], Letizia Spampinato[2]

[1]*Università di Catania, Dipartimento di Matematica e Informatica, Catania, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*

Geophysical surveillance of active volcanoes is routinely performed mainly by observing the patterns of seismic activity and ground deformation. Seismic activity is regarded as a critical indicator, often a reliable short to midterm (days to weeks) eruption forecaster and a marker of the level and evolution of ongoing volcanic activity. We can distinguish two different groups of seismic signals in volcanic areas—those associated with shear failures in the volcanic edifice, which are called volcano-tectonic (VT) or high-frequency earthquakes, and the seismic signals associated with fuid processes, including long period (LP) events, very long period (VLP) and volcanic tremor. Some recurrent patterns can be recognized in the seismic amplitude time series. Particular volcano states such as lava fountain activities may have a recognizable seismic amplitude pattern.

The task of extracting previously unknown recurrent patterns (also called motifs) from available data is a crucial step in geophysical time series analysis. Algorithms searching for similar patterns are widely used in seismology both when the waveforms of the events of interest are known and when there is no a priori-knowledge. Such methods usually make use of the cross-correlation coefficient as a measure of similarity; if there is no a priori knowledge, such methods, based on cross-correlation coefficient, behave as brute-force searching algorithms. The disadvantage of these methods, preventing or limiting their application to very large datasets, is the computational complexity.

In this work, we apply a brute-force algorithm for motif discovery, the Mueen-Keogh (MK) algorithm, to investigate recurrent patterns within the seismic amplitude time series of the Mt. Etna 2011 periodic eruptive activity (1 January - 16 November 2011). To this end, the seismic amplitude time series were computed using a root mean square (RMS), which provides information on the volcano states and/or external seismic sources. Although belonging to brute-force methods, the MK algorithm enabled us to reduce the computation time, required to find motifs in the investigated time series, by means of two optimization techniques: the early abandoning concept and the space indexing. By adequately tuning the input parameters of the MK algorithm we found eight motif groups characterized by distinct seismic amplitude trends, each related to a different phenomenon. In particular, we observed that earthquakes are accompanied by sharp increases and decreases in seismic amplitude whereas lava fountains are accompanied by slower changes. These results demonstrate that the MK algorithm, because of its particular features, may have wide applicability in seismology.

Monitoring volcano activity through Hidden Markov Model

Carmelo Cassisi[1], Marco Aliotta[1,2], Andrea Cannata[2],
Placido Montalto[2], Michele Prestifilippo[2], Domenico Patanè[2]

[1]*Università di Catania, Dipartimento di Matematica e Informatica, Catania, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*

Seismic RMS is one of the most used parameters to monitor volcano activity. Similar to all the time series, also RMS can be investigated by data mining techniques. At Mt. Etna, the broadband permanent seismic network is composed of 32 stations equipped with broadband, acquiring seismic signals in real-time at a sampling rate of 100 Hz. The signal recorded by the vertical component of a reference station, located near South-East crater, was filtered in the band 0.5-5.5 Hz and the RMS was calculated on 10-minute-long moving windows. The volcano states ("quiet", "pre-fountain", "fountain", "post-fountain") are strongly related to the RMS trend, and their automatic recognition can be very useful for monitoring purpose. Since RMS behaviour is considered to be stochastic, we can try to model the system, assuming to be a Markov process, by means of the Hidden Markov Models (HMMs). HMMs analysis seeks to recover the sequence of hidden states from the observed emissions. In our framework, observed emissions are characters generated by the SAX technique, which maps RMS time series values with discrete literal emissions. The experiments show how it is possible to guess volcano states by means of HMMs and RMS.

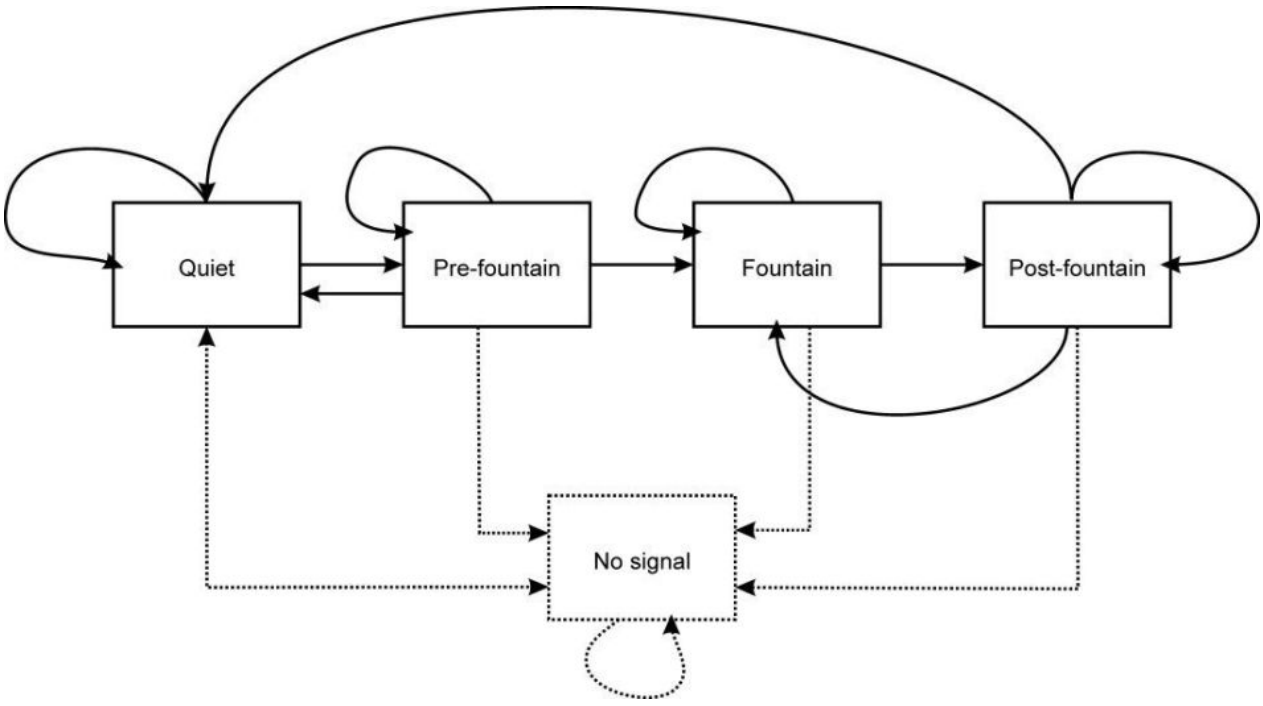

Figure 1. Graph representing volcano states and transitions between them.

The 2012 explosive activity at Bocca Nuova (Mt. Etna): Preliminary correlation between thermal data and acoustic signal

Francesco Ciancitto[1], Mariangela Sciotto[1,2], Laura Spina[1,2], Luigi Lodato[1], Eugenio Privitera[1], Daniele Andronico[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Catania, Italy*

Bocca Nuova, one of the four summit craters of Mt. Etna, resumed its activity late in the evening of 2 July 2012 after about a year of relative quiescence. The last volcanic activity at this crater occurred between June and July 2011, when a vent opened at the E base of the almost 100 m-depth crateric terrace, producing alternatively ash emissions, Strombolian explosions and block ejections. The 2012 eruption took place close to the 2011 vents and was initially characterized by low, discontinuous Strombolian explosions. The increasing of this activity both in frequency and intensity led in a few days to the building of an intracrater scoria cone several tens of meter-high which flanked the NE wall of the Bocca Nuova crater. Small lava flows were also repeatedly emitted by the active vent(s), descending the slopes of the cone and partially overlapping each other.

Figure 1. Misure Session at Bocca Nuova (Etna), on the evening of 30 July 2012. Photo taken by Francesco Ciancitto.

Six campaigns were conducted with the aim of characterizing the dynamic of the explosive activity. During the 30 July survey, in particular, we combined the acquisition of both thermal imagery and acoustic signals between 18:38 and 19:38 GMT. Thermal data was obtained by using a Forward-Looking Infrared (FLIR) SC660 camera with high-resolution capability, which includes a 640 x480 infrared detector operating in the 7.5-13 μm spectral range; images were acquired at 60 fps and stored in standard JPEG format. During the acquisition, we also recorded the explosive activity by a Nikon 1 V1 camera at 60 fps. The acoustic signal was acquired at a sampling rate of 100 Hz with a G.R.A.S.S. microphone characterized by a sensitivity of 50 mV/Pa in the 0.3-20000 Hz band. The thermal and acoustic data was synchronously analyzed by means of a specific software enabling us to focus on point to-point correlation among acoustic signals and infrared images.

In general, during the explosive activity the thermal and infrasonic signals are propagated from the explosion source at different velocities. The delay between the arrival of the two signals at co-located thermal and infrasonic sensors can thus be used to constrain source depth and/or velocity at which the ejecta shell is travelling [Ripepe et al., 2002].

In the study period, the explosive activity occurred from a single vent located at the summit of the scoria cone. It consisted of Strombolian explosions quite regular in terms of frequency (one explosion each 1-4 s) and intensity, with coarse, up to meter-scale incandescent material reaching heights of tens of meters above the cone and falling back on its slopes. Our preliminary analysis shows that the eruptive process was almost regular, allowing to recognize a typical repetitive acoustic signal associated to the single explosive event. The analysis of the thermal data showed that maximum apparent temperatures recorded on 30 July between 18:38:00 and 18:50:00GMT was 800 °C, in particular the range from ~500 to 800 °C. The acoustic signal recorded during the field experiment was analyzed in the time and frequency domain. The full time series was characterized by means of RMS envelope and periodicity investigation in order to verify if the Strombolian activity exhibits an evolution in time. Beside on the continuous recording, waveform and spectral analyses are performed on the individual infrasound transients with the aim of addressing source

mechanism and dynamics of the explosive activity. Furthermore, the signal acquired during the campaign is compared with the signals recorded by the permanent infrasound network in the same time interval.

The multidisciplinary approach followed on 30 July field experience represents a case study to repeat and implement in the future on Mt. Etna and other volcanoes characterized by persistent activity. The strengthening of the methodology may be used to identify different types of signal and is aimed at the automatic detection of the different types of explosions.

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Ferdinandea 2012: the oceanographic cruise on the Graham Bank, Strait of Sicily

Mauro Coltelli[1], Giuseppe D'Anna[2], Danilo Cavallaro[1], Fausto Grassa[3], Giorgio Mangano[2], Raffele Azzaro[1], Antonino D'Alessandro[2], Giuseppe Passafiume[2], Alessandro Amato[2], Sergio Gurrieri[3], Domenico Patanè[1], Stefano Gresta[2]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy*

The Graham Bank, located 25 miles SW of Sciacca, together with the Terrible and Nerita banks forms a large submarine high-relief of the Strait of Sicily. It is formed by two volcanic centres, including the relict of the short-lived Ferdinandea Island emerged during the famous 1831eruption.

On July 2012 the Istituto Nazionale di Geofisica e Vulcanologia carried out a multidisciplinary oceanographic cruise focused on the mapping of the volcanic centres of these submarine banks and on their geophysical and geochemical monitoring.

During the cruise, performed with the R/V Astrea of ISPRA, three OBS/H (Ocean Bottom Seismometers with Hydrophones) were deployed close to the three banks for recording seismo-acoustic signals, a high-resolution bathymetric survey was carried out, a rock sample was taken from the sea bottom and the gas was collected from a fumarole on the Graham Bank.

The morphobathymetric analysis of the multibeam data allows us to identify ten conical shaped submarine volcanic structures scattered on an area extended from 50 to 60 km offshore Sciacca on the Sicily western coast. They appear rightly disposed along a 13 long and 3 km large NS trending belt.

The two submarine truncated cones, belonging to the Graham Bank, lay on the seafloor between 130 and 180 m deep (Figure 1). The smallest of them, the Ferdinandea remains, rises up to 150 m respect to the surrounding seafloor with the top located 9 m b.s.l. Very steep layers radially dipping surround the volcanic neck. The base is elliptical with a NW-SE trending and a 700 m long maximum axis. A flat terrace between 30 to 60 m large is located between 35 and 40 m of depth, which presumably corresponds to the lower limit of the waves activity. The slopes appear very regular without evidences of active erosive processes; in agree with its very young age.

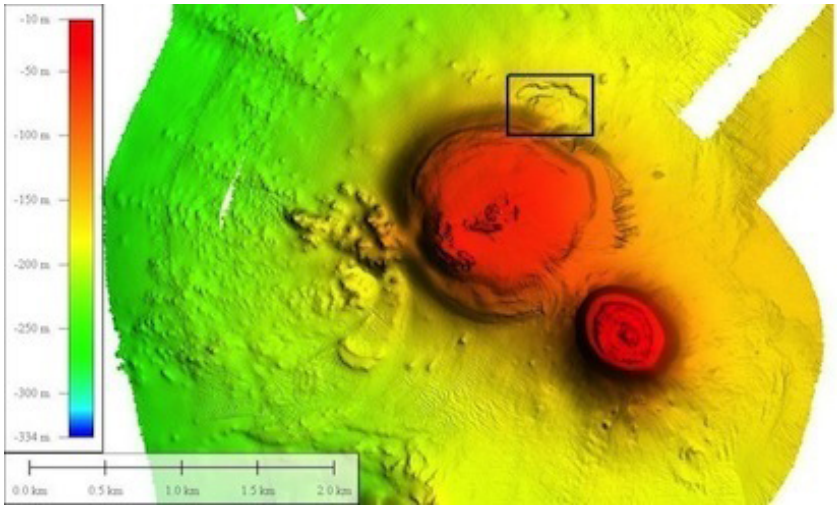

Figure 1. The high-resolution bathymetry of the Graham Bank. The smaller truncated cone on the right side is the shoal formed by the remains of the Ferdinandea Island grown up during the 1831 eruption; the larger shoal on the left side was formed by an older non dated eruption, it presents many gas emissions mainly from the area inside the black box where gas from a fumarole was sampled by the ROV of R/V Astrea.

The second volcanic centre of the Graham Bank is the largest edifice among the ten mapped with a basal diameter of 1.5 km and a quite regular circular shape. The slopes show several evidences of erosive activity proving an older age. The low NE flank appears characterized by irregularly shaped scars probably formed by the hydrothermal alteration of fumaroles as shown by the bubbles upraising recorded by the multibeam sonar and ROV images. The top (-35 m) is formed by rocky structures located at a depth of 50-60 m, and at the base of the W flank a 800 m long lava flow field occurs (as proved by ROV images), which represents the only one recognised in the mapped area.

On the NE side of this cone, where the voluminous rising of bubbles was observed, the gas from a fumarole at 155 m depth was sampled. A preliminary analysis of this gas allows us to know its composition: CO2 (~ 80 mol%), N2 (~ 10 mol%), CH4 (~ 8 mol%) and He of mantle origin. The isotopic compositions of He and C reflect a clear crustal-magmatic origin. Post-genetic processes such as selective dissolution, mixing with hydrocarbons and N-rich gas of sedimentary origin, were also identified.

Some 2 km south of the Graham Bank, between 180 and 230 m of depth, other three cones appear. The first one shows a shape similar to an amphitheatre opened westward, at the base of which a small canyon opens out. The next two cones are very similar showing a circular shape with a 700 m large diameter and a terraced area at some 90 m of depth. Their similar morphology allows us to infer a close age.

Other 2 cones are located between 2 and 4 km north from the Graham Bank. The tops are 100 and 125 m b.s.l. while their bases are respectively 650 and 900 m large. They have no terraces on top and present several evidences of gravitational instability on their slopes, highlighted by hummocky morphologies at their bases.

The northernmost side of the mapped area is quite complex for the presence of three truncated cones with flat terraces at some -80 m. Their shapes are irregular, width between 500 to 900 m, showing evidences of an intense erosive activity with large blocks (up to 200 m) that seem to have been transported gravitationally downslope. Their similar morphology allows us to infer a temporally close eruptive activity.

The framework presented is preliminary, further investigations are planned. In October 2012 a new cruise will recover the OBS close to the Graham Bank, to see the ongoing seismicity, collect more gas samples and geological data to unveil this volcanic field that even if active in historical times, is still almost completely unknown and not yet monitored.

Two-component mantle below Mt. Etna (Italy): evidences from noble gases and geochemistry of primitive volcanites as compared with nearby Hyblean mantle

Alessandra Correale[1], Mauro Martelli[1], Antonio Paonita[1], Andrea Rizzo[1], Silvio Rotolo[2], Rosa Anna Corsaro[3], Valeria Di Renzo[4]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy
[2]Università di Palermo, Dipartimento Scienze della Terra e del Mare, Palermo, Italy
[3]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy
[4]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Italy

We investigated some selected primitive products (<15ka) from Mt. Etna in order to characterize the mantle source below the volcano. We performed a general geochemical study comprehensive of major, trace elements and Sr-Nd isotopes in the bulk rock, coupled to noble gases analyses from fluid inclusions retained in minerals.

The studied samples, classified into the Totally Alkali Silica Diagram as basalts, trachybasalts and basanites, exhibited high Mg content (6.3-17.5 wt%) so testifying that they represent some among the most primitive products of Etnean history. Patterns of REE are comparable for the different rocks and characterized by variable LREE enrichments with respect to MORB (Lan/Ybn=11-26) while some selected trace elements ratios (i.e., Ce/Yb vs Zr/Nb and Th/Y vs La/Yb) are characterized by well-defined variation trends. In the hypothesis that such variability was due to a different degrees of melting of a common mantle source, we performed numerical simulations of mantle partial melting by MELTS code. These calculations allowed to assess the pristine trace elements content of the Etnean mantle source, putting into evidenced that the mantle source is common at all the investigated products and shows notable similarity to that of Hyblean lithosphere. The results relative to analyses of Sr-Nd and He (87Sr/86Sr= 0.703321-0.703901, 143Nd/144Nd= 0.512836-0.512913 and 3He/4He=6.7-7.6 Ra) highlighted a variable degree of geochemical evolution and also in this case evidenced the relation existing between Etnean and Hyblean mantle. In fact the less evolved isotopic composition of Sr, Nd and He relative to Spagnolo, probably approaching the isotopic marker of Etnean mantle source, falls in a range close to the field of Hyblean mantle. Also, correlations between noble gases and trace elements are in favour of the close similarity between the Hyblean and Etnean mantle. In this framework, the estimated chemical and isotopic compositions of the Etnean mantle source fall along mixing curves between the peridotite and pyroxenite compositions forming the Hyblean mantle. On this bases, the investigated Etnean volcanics would origin from melting of a two-component mantle where pyroxenitic veins furrow for about 10-20% a peridotitic matrix.

If we interpret the most primitive Sr-Nd-He values measured into the dataset as reflecting the isotopic marker of Etnean mantle source, we need additional processes in order to explain the evolved isotopic values of Sr-Nd-He measured into some products. Variable degree of crustal contamination by fluids, as well as magma aging could be a responsible for the discussed isotopic variations. In these context, different time of storage into the Etnean reservoir and/or various rates of magma rise could be key parameters in preserving the original isotopic marker of the Etnean source.

Mt. Etna volcanic activity from 2007 to 2012: petrologic data to infer mechanism driving recurrent lava fountains at South-East crater

Rosa A. Corsaro and Lucia Miraglia

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy

The South-East is the youngest of Mt. Etna's summit craters and the most active during last decades. It has often produced episodic eruptions, lasting from a few weeks to months, and consisting in recurrent lava fountains generally associated with lava flows emission. In recent decades, episodic activity at SEC occurred 1989 (16 lava fountains in September), in 1998–99 (22 from September 1998 to February 1999, 2000 (64 from January to June), 2001 (15 from June to July), 2006 (18 from August to December), 2007-08 (7 from Mar 2007 to May 2008) and 2011-2012 (25 from Jan 2011 to April 2012).

We focus on the volcanic activity from 2007 to 2012 when the episodic lava fountains at South-East crater (SEC) were associated to a flank eruption from 13 May 2008 to 6 July 2009. We analyzed the rock samples regularly collected during the monitoring activity performed at INGV-OE and studied them for the petrography, minerals/glass chemistry and bulk rock major and trace elements composition. All the products are porphyritic K-trachybasalts with a total phenocrysts abundance (P.I.) varying from 10 to 30% in volume. The time-related distribution of both major and trace elements show trends with significant variations which may be explained in terms of mixing between compositionally distinct batches of magma associated with minor fractional crystallization. Petrologic data, integrated with volcanological observations and literature information, allowed us to speculate about the mechanism driving the episodic activity at SEC which results to be strongly controlled by dynamics of gas-magma mixture at the top of SEC reservoir. Finally we hypothesize the possible causes leading to the shift from the episodic activity at SEC in 2007-08 to the flank eruption starting on 13 May 2008.

Bromine in basaltic volcanic systems: experimental study on fluid/melt partitioning coefficient

Michela Costa[1], Alessandro Aiuppa[1,2], Giada Iacono Marziano[3], Antonio Paonita[2]

[1]*Università di Palermo, Dipartimento Scienze della Terra e del Mare, Palermo, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy*
[3]*Institut des Sciences de la Terre d'Orléans, Orléans, France*

Halogens, in spite of their low concentrations in volcanic gases and plumes, play a central role not only in magmatic systems processes but also in atmospheric chemistry. In fact, reactive halogen species have been shown to participate in several reactions implicated in tropospheric O3 destruction [Aiuppa, 2009; Bobrowski et al., 2003; Bobrowski et al., 2007; Von Glasow et al., 2009; Bureau and Mètrich, 2003]. This highlights the importance of volcanic Br in tropospheric processes and strongly suggests that volcanoes may seriously impact the chemistry of the atmosphere by causing localized ozone depletion, and eventually small ozone "holes". Unfortunately, our current state of knowledge concerning bromine behaviour in magmatic systems is still rather scarce [Aiuppa et al., 2009; Pyle et al., 2009], so a quantitative model of the mechanisms controlling Br degassing from subaerial volcanism is currently impossible.

In order to understand the degassing behaviour of bromine in volcanic processes, a fundamental step is understanding bromine fluid/melt partitioning coefficient, which has not been investigated yet in basaltic melts. In this context, our work has been mainly aimed to experimentally investigating the distribution of Br between a basaltic melt (Mt. Etna, Italy) and a coexisting fluid phase containing H2O, starting from known concentrations of Br added as NaBr. All experimentes were carried out at ISTO-CNRS of Orléans (FR) using rapid-quench autoclaves with a run duration of 6-8 h. In order to reproduce typical conditions of the shallow plumbing system of Mt. Etna, the pressure range we explored was in the range 100 bar to 1000 bar. All experiments were performed at T=1200°C (high enough to ensure superliquidus conditions) and redox conditions kept near the nickel-nickel oxide buffer (NNO). Major element compositions in final glasses were measured by electron microprobe at ISTO, whereas bromine measurements were performed by LA-ICP-MS at INGV of Palermo. Water contents were measured by FTIR analysis at University of Palermo. The average fluid-melt partitioning coefficient of Br (DBrf/m) over the range of Br concentrations was derived on a weight basis by plotting the calculated concentrations of Br in fluid phase versus the measured ones in the melt.

In our experiments, Br was found to strongly partition into the fluid phase. This is in agreement with what Bureau and Mètrich [2003] reported for an albitic composition and it means that volcanic Br contribution to the atmosphere may be significant. Since no experimental data on DBrf/m in basaltic melts have ever been obtained so far, our study contributes to fill the lack of knowledge concerning bromine. In fact, coupling together our experimental results with measurements of volcanic plume compositions at Mt. Etna [Aiuppa et al., 2002, 2004] and with information derived from melt-inclusion records, our work can constrain the true Br contents dissolved in Etnean magmas at depth and thus hopefully open the way to constraints Br behaviour during volcanic degassing paths.

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INGV OE project of Servizio Civile "Earth in movement: geodetic monitoring in volcanic and seismic areas of Sicily"

Fabrizio Cultrera[1,2], Antonio D'Agostino[1,2], Sonia Fagone[1,2], Tiziana Fisichella[1,2], Carmelo Giardina[1,2], Ambra Mantovani[1,2], Felicia Pidone[1,2], Eleonora Primavera[1,2], Andrea Salvia[1,2], Alessandro Bonforte[1], Salvatore Gambino[1], Francesco Guglielmino[1], Mario Mattia[1], Giuseppe Puglisi[1], Danilo Reitano[1], Rosanna Velardita[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*Servizio Civile Nazionale c/o INGV-Catania, Catania, Italy*

The Servizio Civile Nazionale (SCN, born in 2001 - Law 64) represents an opportunity for youth, aged between 18 and 28 years, to dedicate a year of their lives in favor of a solidarity commitment and also enables institutions to rely on a team that, stimulated by the possibility of a qualifying experience, guarantees a continuous and efficient service. The SCN intervention areas can be ascrived to the following sectors: assistance, civil protection, environment, heritage and culture, education and cultural promotion, civil service abroad. The Istituto Nazionale di Geofisica e Vulcanologia (INGV) has been accredited by the SCN for Sector B Civil protection and research. In 2011 the Osservatorio Etneo of INGV has promoted a project entitled "Earth in movement: geodetic monitoring in volcanic and seismic areas of Sicily" The project's activities concern the geological context of the whole Sicilian Region, with a particular attention to the main seismic areas (M. Iblei and M. Peloritani) and to the active volcanoes (Etna, the Aeolian Islands and Pantelleria). The main purposes of geodetic monitoring in volcanic and seismic regions are to recognize phenomena that could represent precursors of the eruptive activity and to characterize the deformation fields. The geodetic monitoring system, run by Osservatorio Etneo of INGV, is performed by a network of sensors, installed in Sicily and Calabria, that can be grouped into permanent and discrete GPS stations networks, for continuous and periodic measurements respectively and in, tilt or strain gage stations networks.

Ten volunteers are giving their contribution to achieve the specific goals of the project, which include: enhancing the efficiency of observational systems of the monitored areas, the improvement of archiving and preservation activity of data, better diffusion of the monitoring and surveillance activities carried out by the Sala Operativa of INGV-CT.

The project activities, divided into four working groups, will now be briefly described:

1. GPS permanent networks and web services.
   Two volunteers are involved in a series of tasks that have, as their ultimate aim, the definition of the cause-effect relations between the volcanic activity of Mt. Etna in the last ten years and the movements recorded by the CGPS network, located on the eastern slope of the volcano. The volunteers will also participate in all the phases of the acquisition-transmission-processing chain of the CGPS network, in order to learn technical and scientific notions, with the purpose of developing and improving specific aspects of the network.
2. GPS discrete networks, remote sensing and web services.
   One of the three volunteers of this workgroup has the task to handle the SAR data processing and their subsequent storage on a WEB-GIS. The other two volunteers are responsible for the maintenance and improvement of the geodetic networks and instrumentation, with the periodic review of the geodetic benchmarks, the identification of new sites for continuously improving network geometries and collaboration in implementing mobile stations and section web database; they also have the task to manage, store and process the GPS data of the current and past campaigns relating to the Sicilian Region, converting the files in the universal Rinex format. All three volunteers will support the execution of geodetic measurement campaigns (leveling, EDM, GPS and TLS).
3. Tilt networks and data analysis for "Sala Operativa".
   Two volunteers are responsible of the tilt data reorganization, acquired by the permanent tilt networks, in order to optimize the old database and create new database by area and by reference station. They will also realize a report with the tilt variations recorded during the 2011-2012 lava fountaining episodes occurred at Mount Etna also considering their relationship with other data.

4. Management of the informatics structure of the "Sala Operativa" and web services.
   Three volunteers are involved in the Sala Operativa activities, a strategic functional unit for seismo-volcanic monitoring of the Sicilian Region. The contribution of each volunteer is to promote the diffusion about the activities carried out by the institute, as well as in the implementation of procedures for the data migration, acquired from different monitoring systems.

The effect of volcanic ash on environment: laboratory-leaching experiments on fresh and long-term exposure ash samples

Maria D'Addabbo[1], Barbara Bedin[1], Massimo Guidi[2], Roberto Sulpizio[1]

[1]*Università degli Studi di Bari "Aldo Moro", Dipartimento di Scienze della Terra e Geoambientali, Bari, Italy*
[2]*CNR-Istituto di Geoscienze e Georisorse, Pisa, Italy*

Generation and dispersal of volcanic ash during explosive eruptions can impact the environment at a serious level. Ashfall on natural waters and water supplies produces turbidity, induces pH variations and alters the natural concentrations of chemical elements.

We present here a study on ash leachates carried out on different samples of volcanic ash from fresh and long-term exposure ash samples, in order to evaluate the different release of chemical compounds in the environment. Samples from the eruptions of Mt. Etna (Sicily) of April 24, 2011 and August 12, 2012 represent an opportunity to study leachates on fresh and not yet rain-washed samples. Long-term exposure samples were collected from some explosive eruptions of Campi Flegrei and Somma-Vesuvius, and allowed to determinate the potential release of chemical compounds from old ash samples.

Both fresh and old samples have been characterised by XRF on bulk rock and SEM-EDS on glass and mineral phases. Leaching experiments were carried out using mQ-water and water samples from Lake Ohrid (Macedonia-Albania). Both waters were previously characterised using surface electrode, gas electrode and ion-chromatography. During the experiments the pH variation, and the concentration of chemical compounds (including NH3) were determined. These data, although preliminary, represent a first order assessment of potential environmental impact of volcanic ash.

Tremor-based real time monitoring and early warning on Etna Volcano (Italy): technical aspects and methods

Marcello D'Agostino[1], Giuseppe Di Grazia[1], Ferruccio Ferrari[1], Horst Langer[1], Alfio A. Messina[1,2], Danilo Reitano[1], Salvatore Spampinato[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione Geomagnetismo, Aeronomia e Geofisica Ambientale, Roma, Italy*

Twenty-five lava fountains occurred on Mt. Etna from January 2011 to April 2012. In summer 2012 volcanic activity resumed in a milder form within the Bocca Nuova crater, before it came to an essential halt in August 2012. All these unrests offer rich material for testing automatic procedures of data processing and alert systems, running 24/7, in the context of volcano surveillance. We focus on the seismic background radiation – volcanic tremor – which plays a key role in the monitoring of Mt. Etna. Since 2006 a multi-station alert system has been established in the INGV operative centre of Catania exploiting STA/LTA ratios. Besides, also the spectral characteristics of the signal, which change correspondingly to the type of volcanic activity, can be exploited for warning purposes. Here we apply Self Organizing Maps and Fuzzy Clustering which offer an efficient way to visualize signal characteristics and its development with time. All these techniques allow to identify early stages of eruptive events, and automatically flag a critical status before this becomes evident in conventional monitoring techniques.

Changes of tremor characteristics are related to the position of the source of the signal. The location of the sources exploits the distribution of the amplitudes across the seismic network. The locations were extremely useful for warning, throughout both the flank eruption in 2008 as well as the 2011 lava fountains, during which a clear migration of tremor sources towards the eruptive centres could be noticed in advance. The location of the sources completes the picture of an imminent volcanic unrest, and corroborates early warnings flagged by the changes of signal characteristics.

Real time data processing requires computational efficiency, robustness of the methods and stability of data acquisition. The amplitude based multi-station approach is not sensitive to the failure of single stations and therefore offers a good stability. The single station approach, exploiting unsupervised classification techniques, limits logistic efforts, as only one or few key stations are necessary. Both strategies have proven to be insensitive to disturbances (undesired transients like earthquakes, noise, short gaps in the continuous data flow). False alarms were not encountered so far.

Stable data acquisition and processing come with a properly designed data storage solution. The reliability of data storage and its access is a critical issue. A cluster architecture has been realized for failover protection, including a Storage Area Network system, which allow easy data access following predefined user policies. We present concepts of the software architectures deployed at INGV Osservatorio Etneo in order to implement this tremor-based multi approach system. We envisage the integration of seismic data and those originating from other scientific fields (e. g., volcano imagery, geochemistry, deformation, gravity, magneto-telluric). This will facilitate cross-checking of evidences encountered from the single data streams, in particular allow their immediate verification with respect to ground truth.

First studies of urban seismic risk at Mt. Etna Volcano: an application of Disruption Index

Salvatore D'Amico[1], Raffaele Azzaro[1], Tiziana Tuvè[1], Gaetano Zonno[2], UPStrat-MAFA Working Group[3]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Milano, Italy*
[3]*INGV, CNR (Istituto di Matematica Applicata e Tecnologie Informatiche, Milano, Italy), IST (Instituto Superior Tecnico, Portugal), UNISI (Università degli Studi, Siena, Italy)*

The European research project UPStrat-MAFA ("Urban Disaster Prevention Strategies Using MAcroseismic Fields and FAult Sources", Grant Agreement n. 230301/2011/613486/SUB/A5) moves on from seismic risk analysis in four case study areas, i.e., Italy, Iceland, Portugal and Spain. Started in January 2012, the project encompasses actions for the development of probabilistic seismic hazard assessment and disaster-prevention strategies. The problem of the seismic risk is a well-known issue at Etna due to the shallow high-intensities earthquakes frequently damaging the very populated flanks of the volcano. This paper presents the first results on the assessment of the urban seismic risk at a local scale using the "Disruption Index" (DI) approach. The DI provides a global measure of the effects of an earthquake taking into account not only the size of the event (epicentral intensity, magnitude), but also the impact on the local network of lifelines and infrastructures and the system interconnections. To apply DI, we use a probabilistic approach to estimate the seismic input hazard evaluation based on both macroseismic fields and fault parameters. As scenario earthquake, we have selected an event with an epicentral intensity I0 IX EMS (equivalent ML 4.9), located along the S. Tecla fault, similar to the one occurred in 1914. Data used to assess the vulnerability at the urban scale, are organized by a GIS; the main fields of information include building typologies, location of schools and other strategic structures, type and pattern of essential lifelines, etc. The computation of DI is based on the convolution of ground motion parameters and vulnerability/impact values by a Monte Carlo simulation. The results of the first application of DI provide the identification of the municipalities more exposed to seismic risk for the scenario earthquake (Figure 1), and the main elements that contribute to DI. The final value reaches a value of 4 out of 5 in the impact level scale of urban disruption/dysfunction.

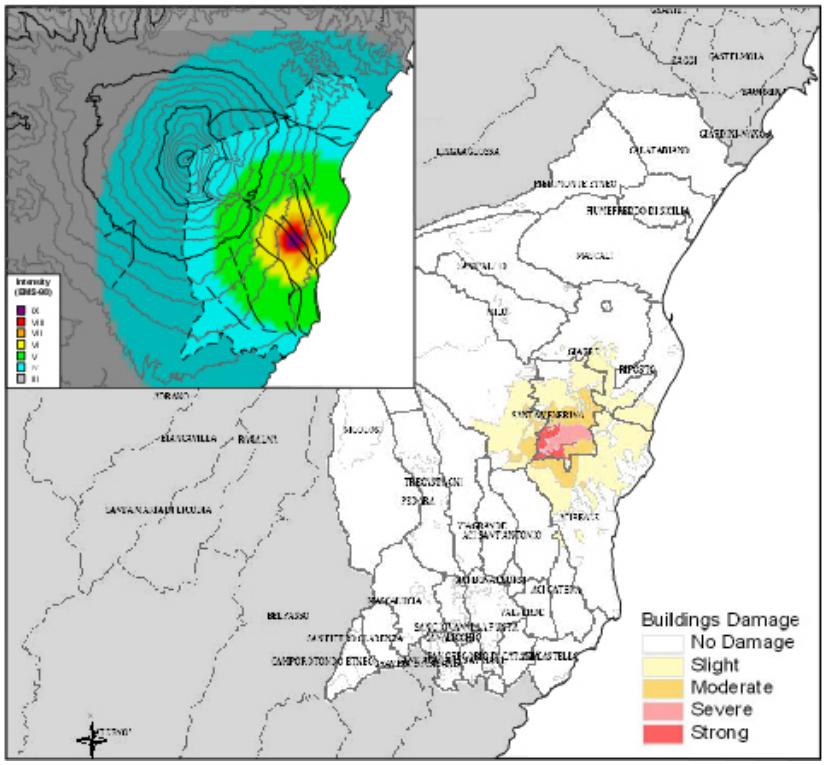

Figure 1. Total expected damage to the building stock. Inset: expected intensity for the seismic scenario of an event with epicentral intensity I0 IX EMS (ML 4.9), located along the S. Tecla fault.

Triggering mechanisms of the 4-5 September 2007 lava fountaining episode

Carmelisa D'Antone[1], Eugenio Nicotra[1,2], Marco Viccaro[1]

[1]*Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Catania, Italy*
[2]*Università della Calabria, Dipartimento di Scienze della Terra, Arcavacata di Rende, Italy*

Since 2001, a new eruptive cycle started at Mt. Etna during which the erupted products gradually moved toward geochemically distinct terms until March 2005. On July 2006, the activity resumed firstly as effusive and then continued as primarily strombolian until December 2006. By contrast, the activity of 2007 was characterized by a succession of paroxysmal events that developed through the South-East Crater, whose increasing intensity and duration culminated with the 4-5 September lava fountaining episode. A lava fountain 350-400-m high and a rheomorphic lava flow 4-Km long, directed into the Valle del Bove, developed in a few hours. Aim of this work is to establish the triggering mechanisms of this violent paroxysm through an integrated study of the textural and compositional features of plagioclase phenocrysts, since plagioclase crystals are highly sensitive to changes of magma composition, pressure and temperature. Crystals representative of the various types of textures found were analyzed by SEM-EDS along core-to-rim profiles. Four main textures were identified: a) oscillatory-zoned crystals with compositions that become progressively more sodic toward the rim (two types of oscillation: low amplitude high frequency – LAHF - and high amplitude low frequency - HALF); b) crystals with dissolved or resorbed cores; c) crystals with coarse sieve textures, constituted by glass inclusions variable in size; d) crystals with oscillatory zoning interrupted toward the rim by strongly developed sieve textures. Furthermore, three different populations of coexisting phenocrysts were found, with An content at the core of 80%, 70% and 60% respectively. The presence of at least two magmas in the feeding system was therefore inferred, the first in equilibrium with plagioclase at An60, which was probably located in the upper part of the magma column residing into the open-conduit system, and a second one in equilibrium with plagioclase at An80, which probably occupied the deeper portions of the feeding system. The existence of the third plagioclase population could be explained by assuming mixing between the two end-members. Crystals of this third population also exhibit abundant sieve-textured rims characterized by higher An content at rather constant FeO wt%, which are evidence of destabilization due to recharge of gas-rich magma. Fast ascent of the gas-rich and more basic magma from the deep levels of the feeding system might be therefore viewed as the triggering mechanism of the violent paroxysmal event that took place on 4-5 September 2007.

Diagnostic features of recycled ash fragments during mid-intensity explosive eruptions at basaltic volcanoes

Claudia D'Oriano[1], Antonella Bertagnini[1], Raffaello Cioni[1,2], Massimo Pompilio[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Italy*
[2]*Università di Cagliari, Dipartimento Scienze Terra, Cagliari, Italy*

Understanding eruption mechanisms and processes which occur before, during and immediately after an eruption (i.e. magma mixing, degassing, ascent, crystallization, fragmentation, clast recycling) mostly relies on the study of erupted products, since the inner part of active craters, conduits and sub-volcanic systems cannot be accessed directly. A clear, unequivocal identification of the nature of the different fragments ejected during an explosive eruption represents thus the first and most critical step which affect the variability of data collection and their interpretation. Deposits associated with mid-intense, basaltic eruptions are characterized by the contemporary occurrence of different types of ash fragments, which have a large variability in terms of external morphology; vesicles content, size, and shape; groundmass texture and composition. Some textural characters are related to primary magmatic processes (storage and ascent), but other features can be acquired during or after injection in the atmosphere. For example, depending on energy of the explosion, large part of ejected tephra can fall back into the vent or in the crater area where they are re-exposed to physico-chemical conditions that can be close to magmatic ones. These products can be further engulfed in the following explosions until the final deposition outside the vent area occur.

Repeated cycles of cooling and reheating can induce relevant modifications of juvenile material, which superimpose over to primary textural and compositional information.

In particular the external surface of the ash can change its primary aspect as a consequence of microlite crystallization, vapour-phase sublimation, and ductile deformation at the microscale. The intensity of these modifications is strictly related to the time spent by the ash at high temperature, becoming more and more pervasive with increasing time, up to involve the inner portion of the clasts. The variation of textural and compositional features of the groundmass is in fact another important aspect implied in the recycling process. Randomly scattered dendritic, plumose and spherulitic microlites are observed to grow in the glass. In this last case, it becomes difficult to discern among primary, dense, microlite-rich clasts, recycled juvenile ash and lithic fragments. Diffuse oxide crystallization is often observed both in the glass and around pre-existing crystals, and it results in a strong modification of glass composition.

Identification of recycled clasts provides information about the state of the most superficial part of the conduit, improves the evaluation of the total volume of fresh magma feeding the eruption, including the heat budget, and has strong implications for hazard evaluation.

We propose here some diagnostic features that can help in the identification of ash grains after recycling within the crater area or in the upper part of the conduit. Experimentally recycled ash resulting by heating primary juvenile material under different redox conditions is compared to natural clasts from mid-intensity explosions at different basaltic volcanoes.

Stratigraphic and petro-chemical analysis of core-holes samples located in the West Rift area of Etna Volcano

Emanuela De Beni, Salvatore Distefano, Stefano Branca, Rosa A. Corsaro

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy

Etna Volcano is characterized by three main volcano-tectonic systems of magma ascent: North-East, South and West Rift (NE, S and W respectively). The S Rift has been characterized by the highest number of lateral eruptions, while the W Rift by the lower over the last 400 years [Branca and Del Carlo, 2005]. Anyway, along the W rift magma frequently intruded, for this reason, the study of its eruptive history represents an important step forward in the knowledge of the volcanic hazard. In this area 2 borehole strainmeters were installed (200 m depth), at Mt. Ruvolo (1210 m a.s.l.) and Mt. Egitto (1570 m a.s.l.), to monitoring the ground deformations of Etna [A. Bonaccorso, INGV-OE coordinated this activity financially supported by the FIRB-FUMO project-Workpackage 1]. A multidisciplinary analysis integrating stratigraphic, petro-chemical and radiometric data (in progress) of the Mt. Ruvolo and Mt. Egitto core-derived samples, allowed us to reconstruct the geological evolution of the W Rift starting from the Ellittico volcano [60 ka, Branca et al., 2011] till today. In this work we present the preliminary petrographic and compositional data of the reconstructed stratigraphic sections according to the stratigraphy of the new geological map of Etna Volcano [Branca et al., 2011]. In each core-hole we firstly have identified different lava flows on the base of their lithostratigraphic features and of the presence of unconformities such as paleosol and volcano-clastic deposits. Then we selected 31 samples for the petrographic analysis and 10 for the chemical ones. Moreover, 4 samples were selected to be analysed with the 40Ar/39Ar incremental heating technique already successfully applied on Etna Volcano [De Beni et al., 2011]. Both the core-hole sections are mostly characterized by lava flows succession with pyroclastic and volcanoclastic deposits interbedded. In particular Mt. Egitto is constituted by 8 lava flows overlapped by Mt. Egitto products which are covered by Poggio la Caccia and 1651 lava flows [Branca et al., 2011]. Conversely Mt. Ruvolo section is formed by a complex volcanic succession with 15 lava flows with clastic deposits interbedded. These deposits, located in the lower portion of the core-hole, are debris and alluvial and they mark temporal unconformities in the volcanic succession. These hiatus are probably due to the evolution of the western flank hydrographic setting as already observed in other sectors of the volcano [Branca, 2003]. Mt. Egitto and Mt. Ruvolo volcanics show the petro-chemical features typical of the Mongibello and Ellittico volcanoes [D'Orazio et al., 1997; Nicotra and Viccaro, 2011]. Nevertheless to explain the compositional variations observed within the two stratigraphic successions, further investigations are needed to better understand the magmatic processes (i.e. fractional crystallization, mixing between magmas with different composition) occurring within the plumbing system. The timing of the transition from Ellittico to Mongibello Volcano, and therefore of the magmatic processes involved, can be better assessed only by 40Ar/39Ar dating results. It will be possible to reconstruct, for the first time, the evolution of the eruptive activity during the past 60 ka of Etna Volcano West Rift.

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Exploring separated gas–magma flows in basaltic volcanoes using analogue experiments at a range of scales

Elisabetta Del Bello[1], Edward W. Llewellin[2], Jacopo Taddeucci[1], Piergiorgio Scarlato[1], Stephen J. Lane[3], Mike R. James[3]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione Sismologia e Tettonofisica, Roma, Italy*
[2]*Durham University, Earth Sciences, Durham, United Kingdom*
[3]*Lancaster University, Lancaster Environmental Centre, Lancaster, United Kingdom*

The decoupling of magmatic gas from magma during transport to the surface may result in cyclical and unsteady flow of magma within basaltic conduits. These flows are characterized by low-intensity, impulsive explosions which may recur rhythmically for long periods of time. We present the results of scaled analogue experiments which elucidate the separated flow processes which underpin such eruptions. Experiments are conducted in liquid-filled vertical pipes ranging from 0.02 to 0.2 m in diameter, and 2 to 12 m in height, allowing us to investigate Reynolds numbers 10^-3 < Re < 10^5, encompassing the natural range for volcanoes. The chief novelty of this study is that we explore the role played by the boundary conditions at the top and at the bottom of the pipe: i) the top of the conduit is either plugged, rheologically impeded, or open; ii) the base of the conduit is either closed (zero flux) or held at constant pressure. This latter condition mimics the presence of a magma chamber at the lower end of the conduit.

Our study combines the direct observation of in-conduit fluid dynamic processes with measured pressure variations inside and outside the pipe. Our results illustrate that changing boundary conditions dramatically affects the degree of overpressure acquired by the decoupled gas phase during ascent and, consequently, the explosivity of the eruption. We place our results in the context of field observations and data from Stromboli, and discuss the insights afforded by our experiments into the shallow expansion/explosion dynamics and the interpretation of seismo-acoustic signals.

Unusual lapilli tuff ejecta erupted at Stromboli during the 15 March 2007 explosion shed light on the nature and thermal state of rock forming the crater system of the volcano

Stefano Del Moro[1], Alberto Renzulli[1], Patrizia Landi[2], Sonia La Felice[2], Mauro Rosi[3]

[1]*Università degli Studi di Urbino "Carlo Bo", Dipartimento di Scienze della Terra della Vita e dell'Ambiente, Urbino, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Italy*

Textural and mineralogical study of high-temperature, angular blocks erupted during the Stromboli explosion of 15 March 2007 were used to make inferences on the nature and thermal state of rocks forming the subsurface of the so-called crater terrace of the volcano. The studied ejecta consist of lapilli tuff that resulted from the transformation and high temperature induration (sintering) of the basaltic scoriae, lapilli and ash originally accumulated as loose tephra during the current activity of the volcano. The main processes leading to the tephra transformation were investigated through microstructural observations, minerals and glass analyses (SEM-EDS and EMP analyses). Investigations revealed that subsolidus reactions and partial melting of the tephra occurred, at temperatures higher than 600°C and under variable fO2 conditions from QFM to HM buffering curves. In some blocks evidences of high-T re-heating and partial melting at the expense of secondary hydrothermal minerals was also highlighted. In order to track the subsolidus re-heating history of the basaltic pyroclasts, a detailed study of the pseudomorphic phases and reactions after olivine, driven by iron oxidation under high-T conditions, was performed. Observed mineralogical transformation suggests that the lapilli tuff material, originated from burial of tephra routinely accumulated by persistent strombolian explosions within the crater terrace, were some cases altered by acid fluids circulation and are in any case re-heated due to the isotherm rise forced by high heat flux and gas streaming delivered by the underlying magma system. It is worth noticing that the ejection of these unusual volcanic lithotypes was possible because few days before the 15 March 2007 event, the craters were clogged with lapilli tuff material that slid to the crater bottom between 7 and 9 March. Findings of this study suggest that the scattered permanently active vents and shallow conduits of Stromboli are surrounded sideways and underneath the crater terrace, by a fairly large volume of high temperature rocks with variable degree of compaction, sintering up to partially melted. Such a spectrum of rocks types accord well with a conceptual model of a prominent thermal zoning all around (sideway and upwards) the active magmatic system. We speculate that continuous migration upwards of isotherms, led to transformation and partial melting of the normal strombolian tephra.

Turbulent fountains and jets as an approximation of experimentally generated eruption columns

Fabio Dioguardi, Pierfrancesco Dellino, Daniela Mele, Mariateresa Balzano, Maria D'Addabbo, Giovanni Fanizza

Università degli Studi di Bari "Aldo Moro", Dipartimento di Scienze della Terra e Geoambientali, Bari, Italy

Turbulent fountains and jets form when a dense fluid is continuously injected into a less dense environment [Turner, 1966; Bloomfield and Kerr, 2001; Kaye and Hunt, 2006; Carazzo et al., 2010]. Although eruptive columns during explosive eruptions are multiphase mixtures made of a solid phase (pyroclasts and/or magma droplets) and a gas phase (magmatic gases and entrained air) [Woods, 1988], depending on their bulk density they can be described as turbulent fountains, negatively buoyant jets or plumes [Carazzo et al., 2010]. This approximation is valid as long as the pyroclasts are very fine grained and the times needed for heat and momentum exchanges between the gas and the solid phase are smaller than the characteristic times of the flow. In this case the eruption column can be considered as a fluid whose physical properties are weighted among the phases (pseudofluid approximation [Woods, 1988]).

The behavior of the column is mainly controlled by the density difference between the column and the ambient density, together with the exit conditions of the eruptive mixture quantified by the Reynolds and Froude numbers. If the column bulk density is much larger than the atmospheric density, a fountain is formed, which is characterized by a negative buoyancy and is driven solely by its momentum at the source. In this case the density contrast is so large that there is no entrainment of the surrounding air. Therefore the column maintains its density and, once its kinetic energy is completely converted into potential energy, it falls back and collapses onto the ground.

On the other hand negatively buoyant jets are characterized by a bulk density larger than the atmospheric density, but the density contrast is not as large as in the case of fountains. For this reason entrainment takes place, the column density decreases due to the mixing with the surrounding less dense air and, depending on the vent conditions, the jet reaches the buoyant condition [Turner, 1966] or reverses the flow direction [Bloomfield and Kerr, 2000; Carazzo et al., 2010]. In particular the first case is used for modeling Plinian clouds [Woods, 1988].

Finally, plumes are characterized by a bulk density lower than that of the atmosphere and thus they are positively buoyant from the vent. This is hardly the case of real explosive eruptions.

By means of large scale experiments [Dellino et al., 2007, 2010] we were able to reproduce both fountains and negatively buoyant jets. Here we show that the development of fountains, as their entrainment is negligible, can be described by the Bernoulli equation, which allows us to predict the maximum height reached by the column and the mass flow rate of the collapsing column onto the ground. Moreover the role of entrainment for jets has been experimentally proved, as in this case the application of the Bernoulli equation for predicting the column height results to be not adequate. Finally, a linear relationship between the dimensionless column height and the source Froude number Fr0 has been found, which agrees well with previous experiments on jets for Fr0>3 [Kaye and Hunt, 2006].

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Textural studies and petrological constraints on the 1864-66 basaltic activity and 1.9 ka sub-plinian eruption of the Turrialba Volcano, Costa Rica Central Cordillera

Andrea Di Piazza[1], Claudia Romano[1], Gianfilippo De Astis[2], Gerardo J. Soto[3], Alessandro Vona[3]

[1]Università degli Studi Roma Tre, Dipartimento di Scienze Geologiche, Roma, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione Sismologia e Tettonofisica, Roma, Italy
[3]Instituto Costarricense de Electricidad, San José, Costa Rica

Turrialba is the southeasternmost volcano of the Costa Rica Central Cordillera and together with Irazu Volcano (they are considered twin volcanoes), forms the largest volcanic massif of Central America. According to the few existing studies, the products of the volcano belong to the calcalkaline series ranging from basalt - basaltic andesites to dacites. The stratigraphic record suggests the occurrence of explosive activity, essentially strombolian to vulcanian, with rarely more energetic events such as sub-Plinian eruptions. Effusive activity is also present, with lava flows covering the entire compositional spectrum. Surge deposition suggests also phreatomagmatic events. After the last eruption (1864-66), Central and West craters have displayed weak fumaroles activity, but from 1996 the degassing have become more intense with the extension of the fumarolic field, the opening of new fractures and the occurrence of phreatic explosions. All these events suggest the potential reawakening of the volcano. For this reason, and due to the scarcity of existing studies on the volcano, we decided to carry out a throughout investigation of the volcanic activity concentrating primarily on the last 10 ka: in particular, we chose to focus our attention on two separate eruptions which represent the most likely eruption and the most explosive event to be considered in case of reactivation of the volcano. We therefore consider the last basaltic vulcanian phase (1864-66) and the sub-plinian eruption, dated 1.9 ka, andesitic in composition. We studied the stratigraphy of proximal, intermediate and distal outcrops of the two eruptions, sampling the outcrops at different levels, where textural differences were observed. In each level, 50 pumice or scoriae clasts have been selected to determine density and vescicularity by He picnometer and textural studies. Petrological and minerochemical analyses of the juvenile scoriae, bombs and pumices clasts were performed by a combination of SEM and microprobe techniques.

We analyzed the internal textures and structure of the pumice and scoriae material in order to assess the role of vescicles and microlites in eruptive style and history of the two eruptions.

The complexity of Mt. Etna plumbing system in the last decade of activity as inferred by Sr and Nd isotopic data on products erupted from 2001 to 2012

Valeria Di Renzo[1,2], Rosa A. Corsaro[3], Lucia Miraglia[3], Massimo Pompilio[4], Lucia Civetta[2,5]

[1]*Università di Napoli Federico II, Dipartimento di Ingegneria Civile, Napoli, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[4]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Italy*
[5]*Università di Napoli Federico II Dipartimento di Scienze Fisiche, Napoli, Italy*

Mt. Etna Volcano has undergone a period of intense eruptive activity during the 2001–2012 time interval, with different eruptive styles and regimes.

In July 2001 Mt. Etna resumed flank activity through a complex system of eruptive fissures cutting the NE and the S flanks of the volcano and feeding effusive activity, fire fountains, strombolian and minor phreatomagmatic explosions [2001 Upper (UV) and Lower vents (LV), Corsaro et al., 2007]. On June-July 2002 eruptive activity was concentrated at the summit Bocca Nuova (BN) and NE craters (2002 summit activity), whereas the 2002–03 flank eruption began on October 2002 and involved the opening of eruptive fissures on the NE and S flanks of the volcano ([2002-03 N and S fissures, Andronico et al., 2005] with lava flow output and fire fountaining until 5 November. The eruption continued exclusively on the S flank, with explosive activity and lava flows active in November 2002–January 2003. The 2004–2005 eruption occurred after 20 months of quiescence and was exclusively effusive. Intense eruptions occurred at the SE crater in July–December 2006. These were followed by seven episodes of lava fountaining at the SE crater, from March 2007 to May 2008. On 13 May 2008, a new eruption occurred immediately to the E of summit craters and continued until 6 July 2009. During the 2010, the summit craters were the site of intermittent explosive activity. From January 2011 to April 2012 the volcanic activity occurred essentially at SE crater with 25 episodes of lava fountaining accompanied by lava flows emission. Strombolian explosion and intra-crater lava flows occurred at BN crater in July 2011 and July-August 2012. We present new geochemical and Sr-Nd isotopic data of representative eruptive products of 2001–2012 activity, integrated with available data on 2001, 2002 and 2004-05 eruptions, in order to investigate the complexity of Mt. Etna plumbing system.

The products erupted during the studied period are basalts and K-trachybasalts. They show significative Sr and Nd isotopic ratios variability (87Sr/86Sr from 0.70341 to 0.70366, 143Nd/144Nd from 0.51285 to 0.51287).

The less evolved basaltic magma was erupted from 2001 LV and 2002 S fissures. These products show geochemical affinities in terms of major and trace elements contents, are the more enriched in radiogenic Sr. They are probably representative of a batch of primitive, volatile-rich basaltic magma that rose from 10-12 km depth and suddenly extruded through 2001 and 2002-3 eruptive fissures opened on the volcano S flank, defined as “eccentric” [Rittmann, 1965] or “deep dike-fed’’ [DDF, Corsaro et al., 2009] magma in the Mt. Etna literature.

Magmas at different degree of differentiation were erupted from 2001 UV, 2002 N fissures, and during 2002 summit activity and 2004-2012 eruptions. They are geochemically and isotopically different from 2001 LV and 2002 S fissures magmas, showing also compositional and isotopical variability not explainable by simple closed system fractional crystallization process.

The variation in the 2001-2012 time span of geochemical and isotopic data has been used to better constrain the temporal evolution of the magmatic processes occurring in the plumbing system of Mt. Etna. The main process is probably mixing between compositionally distinct magmas: the deep magma, less evolved, more enriched in radiogenic Sr, as the magma erupted from 2001 LV and 2002 S fissures, and the more evolved, less enriched in radiogenic Sr magmas rising along central conduits, probably coming from 6–4 km depth, which contribute becomes more important trough time and is, up to 2012, the main component erupted.

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Xenopumices from the 2011–2012 submarine eruption of El Hierro (Canary Islands, Spain): Constraints on the plumbing system and magma ascent

Alessio Di Roberto[1], Stavros Meletlidis[2], Massimo Pompilio[1], Antonella Bertagnini[1], Ilazkiñe Iribarren[2], Alicia Felpeto[2], Pedro A. Torres[2], Claudia D'Oriano[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Italy*
[2]*Centro Geofísico de Canarias, Instituto Geográfico Nacional, Santa Cruz de Tenerife, Spain*

The volcanic products emitted during the opening phase of submarine eruptions are very rare and difficult to sample because they are quickly buried under subsequent products. The study of these products and of the xenoliths the may contain provide important information on the dynamics of magma rising and on the possible interactions between the magma and the host rocks, as well as on the chemistry, mineralogy and structure of the crust beneath the volcanic edifice. The submarine eruption that began on October 15, 2011 off the coast of the island of El Hierro (Canary Islands, Spain) offered the rare opportunity to study in detail these products. In this work we analyze the texture, the petrography and the chemical composition of the magma emitted during the first days of the eruption and of xenoliths contained in it. Moreover we simulate the conditions of genesis and ascent of magmas involved in the eruption.

The results demonstrate that the xenoliths derive from the interaction (heating) between the magma feeding the eruption (basanite) and a small batch volume of trachytic magma and its associated halo of hydrothermally altered rocks.

Eruptive dynamics of the 2011 explosive phase of Puyehue-Cordón Caulle eruption (Chile)

Manuela Elissondo[1], Valerie Baumann[1], Costanza Bonadonna[2], Marco Pistolesi[3], Raffello Cioni[4], Antonella Bertagnini[5], Mauro Rosi[3], Patricia Sruoga[6], Rafael Gonzalez[1], Lorella Francalanci[7], Laura Chiari[3]

[1]*Servicio Geológico Minero Argentino, Argentina*
[2]*University of Geneva, Switzerland*
[3]*Università di Pisa, Dipartimento Scienze Terra, Pisa, Italy*
[4]*Università di Cagliari, Dipartimento Scienze Terra, Cagliari, Italy*
[5]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Italy*
National Council of Scientific and Technical Research, Argentina
[7]*Università di Firenze, Dipartimento di Scienze della Terra, Firenze, Italy*

Cordón Caulle Volcano (Central Andes Southern Volcanic Zone, Chile) erupted on June 4th, 2011, from a central vent after 41 years of repose. Cordón Caulle generated at least 5 historic eruptions but all associated with a NW fissure of the Puyehue-Cordón Caulle Volcanic Complex. The 2011 eruption started with a 10-12 km high plume that dispersed most of the tephra towards E and SE. After the initial paroxysmal phase, which lasted about 3 days, the activity continued during several months as low-level ash emissions. Pyroclastic density currents were generated on 5-8 June and affected the Nilahue river valley. Lahars damaged the international road and destroyed a bridge in the Nilahue river. On June 20th lava effusion was also reported. Tephra fallout affected a wide area, including Neuquén, Río Negro and Chubut provinces in the west part of Argentina and even reaching the Central part of Argentina, Uruguay and Southern Brasil. The eruption significantly impacted both the local and regional economy and caused the evacuation of 3500 people in Chile. Air traffic was disrupted in Argentina with a massive cancelation of national and international flights and the temporary closure of several Patagonian airports. Land and water transportation, water and electricity supplies and telephone communications were significantly affected. Health problems related to people exposure to ash were also reported. A first fieldwork was carried out immediately after the first explosive phase (July 2011) followed by a second in May 2012. Eruption stratigraphy was characterized based on more than 50 outcrops identified between 18 and 237 km E from the active vent along the main dispersal axes (total thickness of tephra deposits between 1 and 44 cm). Ten different levels were identified in the field within the tephra sequence, each characterized by grain-size, componentry, density analyses and chemistry. Due to the abrupt changes in the tephra dispersal throughout the first days of the eruption, field data were also cross-checked with wind data and satellite images. Volume, plume height and mass eruption rates of the most explosive phases of the eruption were also derived.

Recent advancements in the numerical modeling of turbulent, stratified pyroclastic density currents

Tomaso Esposti Ongaro[1], Simone Orsucci[1,2], Augusto Neri[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Italy*
[2]*Università degli Studi di Pisa, Italy*

The dynamics of turbulent, stratified pyroclastic density currents are analyzed by means of two- and three-dimensional numerical simulations. By adopting a multiphase flow model and new constitutive equations based on the kinetic theory of gas-particle flows and laboratory experiments, we discuss some of the key issues of the non-equilibrium dynamics of density currents and, in particular, the role of turbulent drag and shear in the sedimentation process, the triggering of fluid instabilities in the development of turbulence, the influence of particle deposition on flow mobility and the interaction of the flow with topographic obstacles. Numerical simulations performed are representative of well-known past events (e.g. Mount St. Helens, Montserrat), possible eruptive scenarios (e.g. Vesuvio, Campi Flegrei) or simplified ideal conditions. A preliminary analysis is carried out to derive an empirical relationship between the adopted input parameters, the flow properties and the hazard associated to the current specific kinetic and thermal energy, as a function of the distance from the source.

The contribution of the "UPStrat-MAFA" EU project in earthquake disaster prevention strategies applied to volcanic areas

Susanna Falsaperla[1], Raffaele Azzaro[1], Salvatore D'Amico[1], Horst Langer[1], Luciano Scarfì[1], Giuseppina Tusa[1], Tiziana Tuvè[1], Gaetano Zonno[1] and the UPStrat-MAFA Working Group[2]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy
[2]INGV, CNR (Istituto di Matematica Applicata e Tecnologie Informatiche, Milano, Italy), IST (Instituto Superior Tecnico, Portugal), LNEC (Laboratorio Nacional de Engenharia Civil, Portugal), CSIC (Agencia Estatal Consejo Superior de Investigaciones Cientificas, Spain), EERC (Earthquake Engineering Research Centre, Iceland)

Disaster prevention strategies are of paramount importance to reduce the high cost of earthquake impact in urbanized areas. Countries such as Italy, Iceland, Portugal and Spain are especially vulnerable in Europe, with many an example of disastrous earthquakes in historical and recent times. For this reason, the European research project UPStrat-MAFA ("Urban Disaster Prevention Strategies Using MAcroseismic Fields and FAult Sources", EU Grant Agreement n. 230301/2011/613486/SUB/A5) has chosen these countries as test sites for assessing probabilistic hazard and seismic risk (Figure 1). In addition to the seismic problem, these areas cover volcanic regions that are also exposed to the destructive effects of volcano-tectonic earthquakes. A general overview of the UPStrat-MAFA project that started in January 2012 (see http://upstrat-mafa.ov.ingv.it/UPStrat/) will be presented, encompassing the shared probabilistic methodologies applied to real data and to synthetic macroseismic fields. These first year results are aimed at: i) highlighting a few of the major disruption nodes in the urban systems considered, and ii) proposing educational information systems able to increase risk awareness in the communities living in the volcanic regions prone to damaging earthquakes.

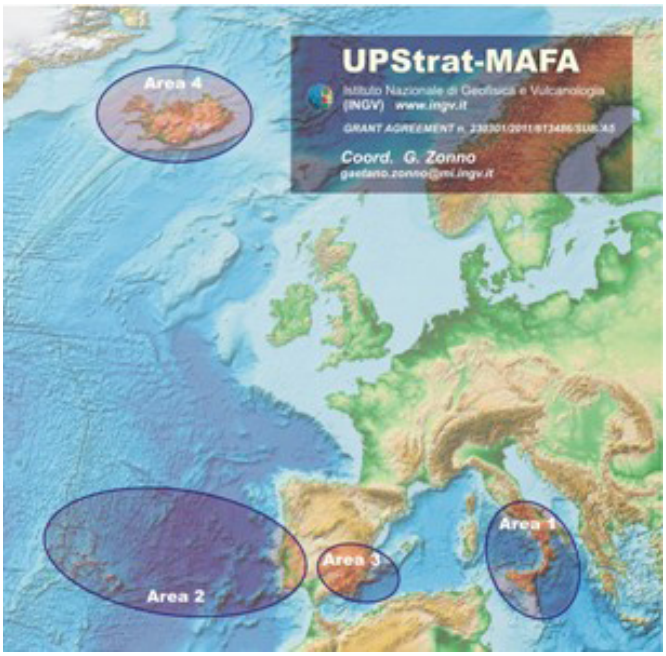

Figure 1. Countries involved in the project UPStrat-MAFA. The areas highlighted and marked as 1, 2, 3 and 4 are test sites for data collection and for assessing probabilistic hazard and seismic risk.

Tilt changes during the Mt. Etna 2011-2012 lava fountains

Giuseppe Falzone[1], Angelo Ferro[1], Tiziana Fisichella[2], Salvatore Gambino[1], Giuseppe Laudani[1], Ambra Mantovani[2]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*Servizio Civile Nazionale c/o INGV-Catania, Catania, Italy*

Lava fountains are powerful gas emissions ejecting lava fragments to heights ranging from tens to hundreds of meters. At Mt. Etna, lava fountains have often occurred during recent decades and most of them took place at the summit South-East Crater, SEC. From January 2011 to April 2012, 25 paroxysms episodes have interested the SEC.

This activity causes the formation of dispersal ash plumes and fall-out deposits that represent hazards for aviation causing repeated closures of the airport. During the 2011-12 SEC paroxysms, the INGV-OE permanent tilt network has recorded systematic variations of fractions of microradians (maximum value is about 1.5 microradians). The duration of these changes is comparable with lava fountains ones, i.e. about few hours.

The clearest variations are visible on tilt radial components indicating a general deflation of the edifice during the fountain. The deflation revealed by the tilt pattern represent the surface effect of a shallow depressurizing source located at about 2-3 km b.s.l.

A time evolution of the tilt observations during all paroxysms at the different stations is here reported. These data associated with volcanological observations furnish new insight on the source and its time evolution.

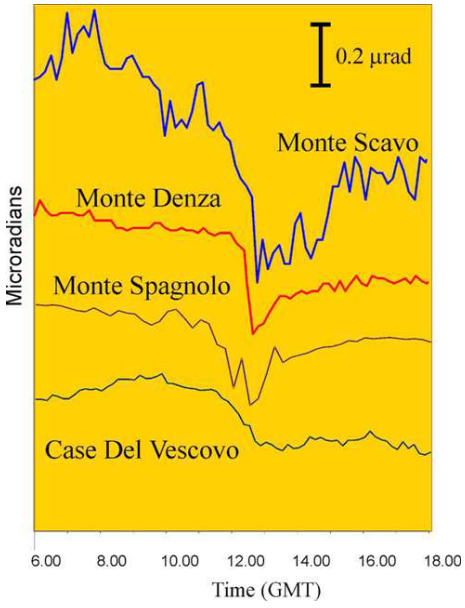

Figure 1. Radial tilt components recorded during the 10 April 2011 lava fountain (ca. 09:00 - 13:00 GMT).

Estimation of overpressure in the asthenosphere, which is caused by partial melting

Oleksander Fedoryshyn

Carpathian Branch of Institute of Geophysics of National Academy of Ukraine, Lviv, Uktaine

The substance of the Earth mantle is inhomogeneous. It consists of a lot of components with various properties. Mathematical modelling of such medium is complicated and in order to receive a complete solution we should be restricted with simple mathematical models. Abnormal properties of mantle substance in the depths of 60-160 km, where asthenosphere is located, explain presence of partial melt in it. This melt as we know is a source of magmatism. Physical properties of the melt strongly differ from properties of a solid phase, therefore the substance of asthenosphere can be modelled as a two-phase material, a solid matrix with the liquid inclusions. During thermodynamic parameters variations complicated processes take place in such substance caused by transition of a solid phase in liquid. This work deals with investigation of thermoelastic properties of a two-phase material of the Earth mantle. Presence of the internal strains caused by partial melting is shown.

Definition of average strains in two-phase heterogeneous mediums, caused by difference of elastic modules of phases. The two-phase statistically inhomogeneous thermoelastic medium consisting of a solid phase and melt is considered. Effective thermoelastic constants for such medium can be found by averaging of the common system of the equations of movement and balance of heat. For each mediums the resolving of such problem is impossible, therefore it is necessary to be limited to correlation approach, that is to accept that physical parameters of phases differ little. Formulas for effective modules of elasticity, thermal strains coefficient and heat conductivity can by defined. We know that when there is no external loading and at uniform heating of the homogeneous medium there is no strains. In heterogeneous medium in this case the average strain will be equal to zero. However, the fluctuations of strains in heterogeneous medium will not be equal to zero, because the thermal strains coefficients in phases are various. Therefore it is interesting to find the fluctuations of deformations and strains. Average square fluctuation of strain and stress can be found in the same method as effective thermoelastic constants. It will depend on the temperature and the difference between the thermoelastic parameters of the phases.

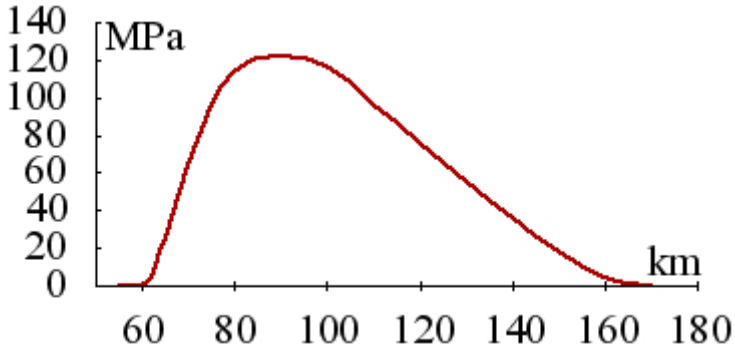

Figure 1. Dependence of overpressure of partial melt on the depth.

Definition of effective thermoelastic parameters of partial melt and their dependences on temperature. The substance of the mantle of the Earth does not have a single melting point. Experiments show that it has a melting region. At a temperature of solidus (Tsol) it begins to melt, and at temperature of liquidus (Tliq) melted completely. Solidus and liquidus temperature is not constant, and depend on the pressure, and hence on the depth. According to the accepted concept in the asthenosphere, that is at a depth of 60-160 km., temperature of environments is a little more the solidus temperature, causing the partial melt [Magnitskiy, 1965]. In this paper we consider the linear dependence of amount of molten material on the temperature and attempt to estimate the change of pressure caused by this melting. Melting is a first order phase transition. At first order phase transitions the first derivatives of internal energy changed discontinuously. Thus, the melting process can be modelled as thermoelastic medium with parameters that depends on temperature discontinuously.

Estimation of internal strains in the partially-melted two-phase medium. In order to analyse the dependence of magmatism on deformations it is of interest to estimate the appearance of internal strains as a result of partial melting. For this purpose, the developed mathematical method of stress fluctuations in stochastical inhomogeneous thermoelastic medium is used. Taking into account that in a homogeneous medium not appear any fluctuations of strains, we can assume these fluctuations are the overpressure, which is caused by partial melting in the asthenosphere. The dependence of additional pressure on depth is shown on Figure 1. As we can see from the figure the rise of temperature of the medium by a few degrees leads to appearance of additional pressure which is comparable to static pressure at the depth.

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Wavelet analysis for the study of the relations among soil radon anomalies, volcanic and seismic events: the case of Mt. Etna (Italy)

Elisabetta Ferrera[1], Salvatore Giammanco[2], Antonio Cannata[2], Placido Montalto[2]

[1]*Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Catania, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*

From November 2009 to April 2011 soil radon activity was continuously monitored using a Barasol® probe located on the upper NE flank of Mt. Etna Volcano, close either to the Piano Provenzana fault or to the NE-Rift. Seismic and volcanological data have been analyzed together with radon data. We also analyzed air and soil temperature, barometric pressure, snow and rain fall data. In order to find possible correlations among the above parameters, and hence to reveal possible anomalies in the radon time-series, we used different statistical methods: i) multivariate linear regression; ii) cross-correlation; iii) coherence analysis through wavelet transform. Multivariate regression indicated a modest influence on soil radon from environmental parameters (R2 = 0.31). When using 100-days time windows, the R2 values showed wide variations in time, reaching their maxima (~0.63-0.66) during summer. Cross-correlation analysis over 100-days moving averages showed that, similar to multivariate linear regression analysis, the summer period is characterised by the best correlation between radon data and environmental parameters. Lastly, the wavelet coherence analysis allowed a multi-resolution coherence analysis of the time series acquired. This approach allows to study the relations among different signals either in time or frequency domain. It confirmed the results of the previous methods, but also allowed to recognize correlations between radon and environmental parameters at different observation scales (e.g., radon activity changed during strong precipitations, but also during anomalous variations of soil temperature uncorrelated with seasonal fluctuations). Our work suggests that in order to make an accurate analysis of the relations among distinct signals it is necessary to use different techniques that give complementary analytical information. In particular, the wavelet analysis showed to be very effective in discriminating radon changes due to environmental influences from those correlated with impending seismic or volcanic events.

Dual explosive activity revealed by petrochemical and mineralogical data on tephra: the historical eruptions of "Pizzo sopra la Fossa" at Stromboli Volcano

Lorella Francalanci[1,2], Eleonora Braschi[1,2], Sara Di Salvo[1], Federico Lucchi[3], Chiara M. Petrone[4]

[1]*Università degli Studi di Firenze, Dipartimento di Scienze della Terra, Firenze, Italy*
[2]*CNR, Istituto di Geoscienze e Georisorse, sezione Firenze, Italy*
[3]*Università di Bologna, Dipartimento di Scienze della Terra e Geo-Ambientali, Bologna, Italy*
[4]*Natural History Museum, Department of Earth Sciences, London, UK*

The Pizzo-Sopra-la-Fossa tuff cone of Stromboli Volcano, formed in the depression following the 4 ka Neostromboli-collapse, has been investigated by stratigraphic, petrographic, mineralogical, geochemical and isotopic studies. The Pizzo-Sopra-la-Fossa deposits are presently the remnant of a collapsed tuff cone formed by a thick pyroclastic sequence of bomb, lapilli and ash fallout and surge levels. These deposits are discontinuously exposed in the summit and upper eastern flanks of Stromboli. The main outcrop is located above the active craters where acid fumarolic gases strongly altered the juvenile clasts. For this reason, the Pizzo-Sopra-la-Fossa sequence was poorly studied, although it represents a key point for recognising the recent evolution of Stromboli, being the linking phase between the Neostromboli and the present-day period of activity.

We mainly focussed our studies on Le-Croci outcrops characterized by a 6 meters thick sequence of mainly fall deposits.

Two groups of feeding magmas have been identified, a group constituted by high-K basalts to high-K basaltic-andesites (Pizzo-HKCA) and another formed by shoshonitic basalts (Pizzo-SHO). The two groups can be distinguished on the bases of petrographic, mineralogical and geochemical data. Pizzo-HKCA products have lower phenocryst contents, incompatible trace element abundances and Sr isotopic ratios, with higher 143Nd/144Nd values than Pizzo-SHO. They also show differences in mineral phase composition and zoning.

The two groups of magmas were affected by mixing/mingling processes, but they did not mix each others in the plumbing system. There are also clear evidences that the two magmas were erupted contemporaneously, suggesting the presence of two distinct magma reservoirs, possibly located at different depth.

These data also show that the Pizzo-HKCA products are similar in composition to both the Lower-Sequence found in trenches by Rosi et al. (2000) and the S.Bartolo-lavas, whereas the Pizzo-SHO samples have affinity with the Post-Pizzo-series, which afterward evolved to the present-day activity [Petrone et al., 2009]. Based on these correlations, it has been recognised that this dual explosive activity forming the Pizzo-Sopra-la-Fossa tuff cone occurred only 2 ka ago, possibly along the activation of NE-trending eruptive fractures.

The role of volatiles on plagioclase stability in Mt. Etna magmas

Pier Paolo Giacomoni[1], Gabriele Lanzafame[2], Massimo Coltorti[1], Carmelo Ferlito[2]

[1]*Università di Ferrara, Dipartimento di Scienze della Terra, Ferrara, Italy*
[2]*Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Catania, Italy*

Volcanic volatiles play a fundamental role in magma ascent dynamics and in the eruptive mechanism. At Mount Etna huge amounts of magmatic gases are released during eruptive and non-eruptive periods; SO2 flux measurements indicate an average discharge of 5000 tons/day (e.g. from 1987 to 2001). This poses the problem of understanding the role of volatiles in determining mineral assemblage and textures of phases.

A possible answer can be sought in the plagioclase, which is the most common mineral in basaltic lavas both as phenocrysts and groundmass. Its stability field and composition is dependant on magma composition, but also on temperature (T) and pressure (P). H2O content, in particular, influences the plagioclase liquidus, affecting the nucleation pressure and therefore the depth at which magma crystallizes and determines the composition of the crystal cores.

In this work textural and compositional features of plagioclases from Etnean lavas from the 2001-2006 eruptive period have been studied in detail and related to events of growth or resorption occurring at specific P-T-fO2 conditions and water contents.

Plagioclase cores are often characterized by rounded edges with clear or patchy inner part. Rounded cores suggest the occurrence of deep episodes of dissolution and shallower reappraisal of crystallization. Plagioclase rims are characterized by a dusty rounded envelope associated to An increase testifying a reaction with a more Ca-rich magma. Finally, rims often show alignments of melt inclusions associated to a less calcic overgrowth, interpreted as a degassing driven growth texture, likely occurred during magma ascent prior the eruption. Various models have been applied to define the most important intensive variables of the magmatic system: temperature (T), pressure (P) [Putirka et al., 2005] and oxygen fugacity (fO2) [France et al., 2010]. H2O contents were estimated using the hygrometer of Lange et al. [2009]. These determinations were then used with the MELTS code to i) constrain the plagioclase stability and growth conditions within magma conduit, ii) reconstruct the primitive magma composition and iii) evaluate the role of fractional crystallization during magma ascent.

Models indicate that H2O content of magma reduce the plagioclase liquidus constraining the crystallization at lower pressure with a more calcic composition. Crystallization occurs in a vertically developed and rather continuous polybaric system. Patchy cores form at higher pressure in H2O poor magmas, suggesting that a reservoir or a ponding zone might exist at about 350 Mpa (corresponding to ca 10 km). Clear dissolved rounded cores form between 280 and 200 Mpa (9-6 km). Dusty rims indicate a level at about 150 Mpa (4 km), where most of the mixing processes occur, melt inclusion alignments develop at very shallow level.

These data outline polybaric crystallization with at least two preferential levels, matching well the low-velocity zones recognized with seismic tomography at about 12+3 and 5+2 km [Murru et al., 1995]. Plagioclase composition and stability field outline an increase of dissolved water upward in the magma feeding system.

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Mineral phases as a tool for robust correlation of proximal-distal ash deposits in the central mediterranean area

Raffaele Giordano, Roberto Sulpizio, Alfredo Caggianelli

Università degli Studi di Bari "Aldo Moro", Dipartimento di Scienze della Terra e Geoambientali, Bari, Italy

Tephra layers and Quaternary sedimentary archives constitute a mutual and integrative system capable of providing relevant information for both volcanological (i.e. hazard assessment) and Quaternary science research (i.e. paleoecology, paleoclimatology).

Comparative analysis of glass from proximal and distal deposits sometimes fails in providing a reliable criterion to recognise the source of a tephra (or the related eruption), owing to very similar major element compositions that makes difficult discrimination on a chemical basis. This is particularly critical for both the Campanian trachytic products (i.e. those erupted from Campi Flegrei, Somma-Vesuvius and the Ischia island volcanoes) and for the calc-alkaline rhyolitic products of the Aeolian Islands. To solve this problem, the evaluation of both the mineralogical association, and the chemical composition of the mineral phases included in the proximal tephras is required. With this approach some distinguishing features can be revealed and, if recognisable also in the distal counterpart, would represent a valid tool for correlation. Some successful examples for ther application of the method are (i) the products of Colli Albani containing both leucite and nepheline and not feldspar, or (ii) the Agnano-Monte Spina eruption ascribed to the Campi Flegrei on the basis of biotite absence.

Therefore, creation of a data-base containing compositional data of mineral phases from the proximal deposits, would make microanalysis of mineral phases from distal tephra an important tool to improve the tephro-stratigraphic correlations in the Central Mediterranean area.

Pre-eruptive magma dynamics and geometry of the plumbing system at Avachinsky Volcano (Kamchatka, Russia)

Marisa Giuffrida[1], Marco Viccaro[1], Eugenio Nicotra[1,2], Alexey Y. Ozerov[3]

[1]*Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Catania, Italy*
[2]*Università della Calabria, Dipartimento di Scienze della Terra, Arcavacata di Rende, Italy*
[3]*Russian Academy of Sciences, Institute of Volcanology and Seismology, Piip Boulevard 9, 6*

New constraints on the feeding system dynamics and geometry of Avachinsky Volcano (Kamchatka, Russia) are provided through an integrated study of whole rock geochemistry and textural/compositional features of plagioclase phenocrysts of the January 1991 eruption [Viccaro et al. 2012]. Lavas are tholeiitic (low-K) basaltic-andesites and andesites with no significant changes in composition with respect to the previous Avachinsky historical products. Evolutionary trends defined by major and trace elements suggest that crystal fractionation is the main evolutionary process prior to the eruption. Both MELTS and Rayleigh fractionation modelling for major and trace elements respectively were performed to explain the observed compositions. An isobaric crystallization process was simulated at 150 MPa with temperature ranging between 1150°C and 1000°C, constant $fO2$ (QFM+1) and initial content of dissolved water at 2.0 wt.%, in accordance with the expected physical conditions of crystallization into a magma chamber at ~5.5 km of depth below the volcano summit. The composition of a slightly differentiated melt ($SiO2$ = 53 wt.%) was chosen as starting material, which was obtained from an average of the less evolved products of the whole Avachinsky volcanic record. Results suggest that the evolution from basaltic-andesite to andesitic lavas of the 1991 eruption could reflect fractionation of plagioclase ~An70-82 (3-27 wt.%), augitic clinopyroxene (10-12 wt.%), orthopyroxene (1-4 wt.%) and opaque oxides (2-6 wt.%) during the magma residence into a reservoir at ~5.5 km (150 MPa) of depth. Additional differentiation processes prior to the eruption were constrained through the textural investigation (high-resolution BSE images) and in situ microanalyses for An% and FeO wt.% along core-to-rim profiles on plagioclase phenocrysts. Plagioclases from each analyzed section exhibit a variety of textures indicative of specific dynamics during magma storage and ascent at crustal levels. Crystallization processes near-equilibrium are testified by the development of two zoning patterns with different amplitude and wavelength of oscillation (small and large scale oscillatory zoning). High-disequilibrium textures appear at the cores of the greatest plagioclase crystals (patchy-zoned, coarse-sieved and dissolved cores) suggesting the occurrence of strong destabilization events in the deep portions of the plumbing system. Furthermore, either dissolution/resorption features such as strongly-sieve textures or fast crystallization textures represented by thin Ab-rich envelopes with polygonal alignments of melt inclusions were found at the plagioclase rim. Textural and compositional observations support the existence of at least a large magma body at ~5.5 km of depth, more than several separated batches. The large volume of magma is probably able to buffer minor variations in temperature and/or composition (for example due to magma pulses from depth), thus preventing the development of significant chemical and physical gradients into the chamber. However some extent of convection should take place since both small and large scale oscillatory zoning patterns develop even within the same crystal. At the deeper, undersaturated levels of the plumbing system, magma decompression rates and/or dissolved $H2O$ contents should be different as distinct disequilibrium textures occur at crystal cores similar in size. This observation could be account for the existence of distinct magma ascending pathways toward the main chamber. Distinct texture types at the outer rims cutting the oscillatory zoning envelopes give evidence for further magma ascent and intrusion toward a minor upper reservoir at ~1.8 km of depth, where mingling should take place prior to the eruption. The strongly developed sieved rims point out to a recharge and mixing process as the driving force for the replenishment of the shallower chamber, from which the eruption should be triggered in a relatively short time span ($\leq$ 4 months according with the calculated timescales).

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Calibration of input parameters for the creation of seismic risk scenarios in volcanic areas

Horst Langer[1], Luciano Scarfi[1], Giuseppina Tusa[1], Danilo Galluzzo[2], Francesca Bianco[2], Paola Cusano[2], Gaetano Zonno[3], Alexandra Carvalho[4], Simon Olafsson[5], Rajesh Rupakhety[5], Ragnar Sigbjornsson[5]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Milano, Milano, Italy*
[4]*Laboratorio Nacional de Engenharia Civili, Portugal*
[5]*Earthquake Engineering Research Centre, Iceland*

UPStrat-MAFA (Urban Disaster Prevention Strategies using MAcroseismic and FAult Sources) is an European Commission Project in the area of "Developing knowledge-based disaster prevention policies" whose primary aim is to produce a seismic risk analysis for disaster prevention strategies. The project focuses on pilot areas, i. e., Mt. Etna, Mt. Vesuvius and Campi Flegrei Volcanic areas; Azores islands and offshore and mainland of Portugal; Southeast Spain area; South Iceland including Reykjavik surrounding urban area.

The estimation of seismic hazard and risk is based both on empirical relations exploiting already existing data as well as synthetic approaches making certain assumptions on models and parameters. The advantage of using empirical relations relies in the fact that they represent "ground truth", i. e., are not influenced by the ideas and preferences of the modeller. On the other hand, the available instrumental data is typically incomplete, in particular poor with respect to strong earthquakes. This questions the validity of those empirical relations when applied to strong earthquakes.

Instead of simply applying empirical relations to magnitude ranges which were not available in the instrumental data set, we may exploit these data to assess factors governing the radiation of seismic energy in general. In particular, absorption and geometrical decay of radiated seismic energy along the propagation path and local site effects can be effectively estimated from small to moderate sized earthquakes in order to be used for the set-up of relevant scenarios of earthquake loading. Here we present some case studies in order to show how data related to small earthquakes can be exploited for the creation of scenarios of larger events. Large earthquakes imply extended geometrical dimensions, such as source radius, or source length and width. Therefore, a single distance is not representative for all contributing parts of the source area. For our simulation of extended sources we have been using a slightly modified version of the "EXSIM" code, where extended sources are treated as a sum of subfaults. In this context we consider our data set being representative for the subfaults rather than for the entire extended sources.

Melt inclusion study on the pantelleritic Plinian eruption of the Green Tuff, Pantelleria Island

Giovanni Lanzo[1], Patrizia Landi[2], Silvio G. Rotolo[1,3]

[1]*Università di Palermo, Dipartimento Scienze della Terra e del Mare, Palermo, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy*

Pantelleria Island is the type locality for the peralkaline rhyolitic rocks called pantellerites. In the last 50 ka, after the Plinian, caldera-forming, Green Tuff eruption, volcanic activity at Pantelleria consisted of effusive and mildly explosive eruptions which mostly vented inside and along the rim of the caldera producing silicic lava flows, lava domes and poorly dispersed pantelleritic pumice fall deposits.

During the last two decades, a wealth of studies focused on melt inclusions in pantellerite magmas, all converging in underlying the H2O-rich character of these melts together with high contents of halogens. Recent study on the volatile content of pantellerites from Pantelleria yielded a pre-eruptive H2O content ≤4.9 wt.% and P ≤1.5 kb [Gioncada e Landi, 2010; Neave et al., 2012] and chlorine up to 0.9 wt.% for magmas erupted during the most recent effusive and strombolian activity at Pantelleria. Recent experimental data confirmed the H2O-rich character of these magmas [Di Carlo et al., 2010]. However data on pantelleritic magmas emitted during large explosive eruptions associated with caldera collapses, are up to date sporadic and not exhaustive. Our study is aimed to determine the pre-eruptive volatile contents of the pantellerite magmas erupted in the Green Tuff eruption, the last caldera forming event at Pantelleria.

All melt inclusions analyzed have rhyolitic composition (SiO2 70-72 wt.%, Na2O+K2O 10-11 wt.%) and show extreme peralkalinity, with an (Na+K)/Al clustering at 2-2.2. Fluorine in MI range between 0.13 and 0.3 wt.%, while S (< 350 ppm) is close to, or lower than, the detection limit (200-300 ppm) of the microprobe. Glasses of GT, both MI and matrix glass, are characterized by a chlorine content as high as 1.1 wt.%, which remains basically unchanged in the all glass analyzed (between 1 and 1.1 wt.%). This value is higher than that found in the younger pantelleritic eruptions of about 0.2-0.3 wt.%.

Dissolved H2O contents in MI (measured by FT-IR) cover a range from 1.4 to 4.2 wt.%, which is comparable with the H2O measured in MI from pantelleritic pumices erupted during younger effusive, or mildly explosive, eruptions. The maximum values are slightly lower than the highest content of water found in pantelleritic melts at Pantelleria (4.9 wt.%) [Neave at al., 2012]. The CO2 content was always below the detection limit of FT-IR method (50 ppm).

Chemical composition and volatile contents in the pantelleritic melt inclusions of the Green Tuff contributed to:

- derive the entrapment pressure/depth of magma accumulation, using appropriate solubility models;
- compare data derived for the Green Tuff Plinian eruption with data available for effusive and mildly explosive eruption (strombolian), at Pantelleria;
- track volatile build-up with magma evolution, i.e. pre- and syn-eruptive degassing.

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Sulfur isotope composition at Etna Volcano (Italy)

Marcello Liotta, Andrea Rizzo, Antonio Paonita, Antonio Caracausi, Mauro Martelli

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy

Mount Etna is one of the most active volcanoes worldwide. One of its prominent features is the huge amounts of H2O, CO2, and SO2 from the summit craters degassed in the atmosphere. Despite the SO2 flux accounting for only a small fraction (<17%) of the total outgassing budget, sulfur degassing has great implications in the evolution of magma, as a potential trigger of eruptions, and in estimating the magma supply at depth. The isotopic signature of the outgassed sulfur carries information on mantle source of magmas, crustal and hydrothermal contributions to volcanic fluids, and physico-chemical conditions inside the plumbing system. Here we report new data on the sulfur isotopic compositions of fumarolic and plume gases collected at Mount Etna Volcano during 2008–2009. Collected samples display delta 34S values between -1 and +4‰ vs. V-CDT. Within this range, low temperature fumaroles show delta 34S-values systematically higher than high temperature gases and plume. We deduce that such values do not reflect the pristine isotopic composition of S released by magma, but are reasonably affected by post-magmatic processes. On the contrary, we infer that the average delta 34S measured in high temperature fumarole and in plume gases is representative of the magmatic signature and allow establishment of a delta 34S range of ~0±1‰ for magmatic SO2.

Our data of sulfur isotopic composition are compared to those available in literature on S dissolved in primitive melt inclusions hosted in olivines from 2002 lava and in whole rocks erupted in the past 2000 years, showing that delta 34S of magmatic gases is lower than that in the melt. Modeling requires assessment of the fractionation factor between S dissolved in the melt and exsolved in the gas phase (alpha gas-melt). It depends on the speciation of sulfur in both the melt and gas phases, which is in turn strictly related to the oxygen fugacity (fO2) of the magma and to temperature and water fugacity (fH2O) at which the degassing occurs. Within the range of redox conditions reported in literature for Etnean basalts, isotopic fractionation could lead to either 34S depletion or enrichment of the gaseous phase. Nevertheless, the most recent measurements on the oxidation state of sulfur in basaltic inclusions hosted in olivines indicate that nearly all S is dissolved as sulfate (S6+), that can be possible only in oxidized magmatic systems. Under these conditions the exsolved gaseous phase is depleted with respect to the melt, in accordance with our data. In this case, the proposed model of isotopic fractionation due to magma degassing (Rayleigh-type) is able to fit both gas and melt data and to constrain the Etnean magmatic delta 34S to +1±1.5‰ vs. V-CDT. It is remarkable that the assessed redox conditions—which are significantly more oxidizing than previously thought—are able to explain why the dominant sulfur species measured in the Etnean plume is SO2.

The MUVE Museum: didactic approach to the discovery of Middle Latina Valley volcanic field

Federico Lucci[1] and Nando Bauco[2]

[1]*Dip. Scienze Geologiche, Università degli Studi Roma TRE, Italia*
[2]*Museo del Vulcanismo Ernico "MUVE" (Giuliano di Roma, Italia)*

A museum promotes the knowledge through acquisition and conservation, exposition and research of proofs and evidences of a certain matter. These aims are accomplished following few principal points: i) a museum could not be a temporary institution; ii) a museum should be free from market analysis; iii)a museum must be opened to the entire community; iv)a museum collection should growth in time; v)a museum must promote research and divulgation. In this view, a museum is a place where Research, Didactic and Pleasure of Knowledge integrate each other.

The MUVE (Museo del Vulcanismo Ernico) is a very young institution, inaugurated during the Summer of 2009, and it is the result of a deep will of the Local Administration (the Township of Giuliano di Roma, with contributions from Regione Lazio Department) to create a didactic and scientific centre.

Since the Musem must be a permanent structure, the Local Administration decided to restore one of the most important XVII century buildings (the residence of Avv. Adolfo Bretagna) of the old town centre and to convert it into the MUVE.

Since a museum must promote knowledge of community, the second step of MUVE foundation has been the definition of the main topic of the museum itself. Giuliano di Roma is a little town on the western flank of Monti Ausoni ridge (Monti Lepini system), and it is completely edified on the summit of a minor composite ring volcano (pyroclastic and interbedded leucititic lava flows). The volcanic rocks are a living part of Giuliano di Roma, since the old town evolved following the directions of lava flows that constituted a solid basement for buildings; since many structural elements of old houses are made of blocks and columns extracted from major outcrops of leucititic lavas; since many olive trees and grapevines cultivations follow distribution of soils derived from underlying pyroclastics. The matter of course is a museum focused on Giuliano di Roma volcano and in general on volcanism. Even if the economic background is not comparable with major Italian and European realities, the MUVE makes a great effort to assert itself inside the Community.

The MUVE presents "volcano" as a consequence of major crust-mantle events and of magma uprising and cooling, and along an ideal pathway, through dioramas, posters, videos, 3D-models and minerals and rocks expositions, tries to produce a better understanding of volcanic processes.

Figure 1. The MUVE museum is located in the old town centre of Giuliano di Roma (FR).

As written, a scientific museum should also promote research and scientific knowledge production. Giuliano di Roma ring volcano is an eruptive vent of the Middle Latina Valley (MLV) small volcanic field (old named "Vulcano Ernico") characterized by absence of large volcanic edifices (typical, instead, of Roman Magmatic Province (RMP) and by the concomitant emission, during the Middle Pleistocene [Boari et al., 2009], of

magma from sub-alkaline and ultrapotassic/kamafugitic series [Boari and Conticelli, 2007; Boari et al., 2009]. The MLV volcanic field evolved in a tectonic setting where Plio-Pleistocene NNW-SSE extensional elements are cutted by N-S and NNE-SSW younger dextral strike slip faults [Boari et al., 2009; D'Agostino et al., 2005; Sani et al., 2004]: volcanic vents are distributed all following these two major structural trends, that probably represented a preferential path for magma uprising. Moreover recent studies [i.e. Boari et al., 2009] highlight the complete geochemical and isotopic affinities of MLV with RMP. This peculiarity is the focus of a vigorous debate: could MLV mafic-kamafugitic array be a key to understand genesis and relationships between ultrapotassic and sub-alkaline magmas, not only in RMP? Could the MLV volcanic rocks help in constraining a possible model for mantellic(?) source(s) of such undersaturated melts? Could MLV be a case study to understand how mafic magmas uprise to surface?

Probably the newborn MUVE may not give us any definitive answer to these major questions, but our great will is to create, in the future, an archive of MLV volcanic samples open to researchers; to become a referring point for contributions on Middle Latina Valley volcanic field projects; to represent a possible scientific pole for workshops and congresses focused on ultrapotassic/kamafugitic volcanism.

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Cpx-Hbl thermobarometry of igneous mafic rock: possible history of Permian andesitic dyke at Mt. Isadalu Complex (Sardinia, Italy)

Federico Lucci[1], John White[2], Silvia Campagnola[1]

[1]*Dipartimento Scienze Geologiche, Università degli Studi Roma TRE, Italia*
[2]*Department of Geography and Geology, Eastern Kentucky University, USA*

Mt. Isadalu is located to the east of the Gennargentu massif and represents one of the major expressions of the post-hercynian magmatic event affecting the Sardinia Massif. The Carboniferous-Permian intrusive activity has been interpreted as consequence of isostatic equilibrium of the crust-mantle system after the hercynian orogeney [Lucci et al., 2011 and reference therein]. The Mt. Isadalu complex shows an half-ring morphology dissected on the eastern flank by a NNW-SSE left-lateral regional strike slip system. The main body of the ring is composed of alkali-felsic pink granitoids [Lucci et al., 2011]. These granites are associated with rhyolitic pyroclastites (at the center of the complex) and with intermediate porphyry dykes (dacites and minor andesites) [Lucci et al., 2011]. The complex is finally intruded by a late shoshonitic dyke and late-stage quartz pegmatitic veins [Lucci et al., 2011].

The Mt. Isadalu Complex shows porphyric textures for felsic dykes, while oligophyric and aphyric ones are recognized principally in intermediate rocks.

The andesites have a microcrystalline groundmass with idiomorphic plagioclase, amphibole (mainly substituted by Chl-Ep-Tr) and opaque minerals (Ilm, Sph, Usp, rare Al-Cr-Sp); phenocrysts are represented by Ca-amphibole and by plagioclase (An up to 50% at core) albitized at rim [Lucci et al., 2011]. Rare crystals of biotite and relic cores of augitic cpx (in major amphibole phenocryst clots) have been identified [Lucci et al., 2011]. Zorpi et al. [1991] interpreted the isolated phenocrysts of amphibole as possible pseudomorphs of pristine clinopyroxene.

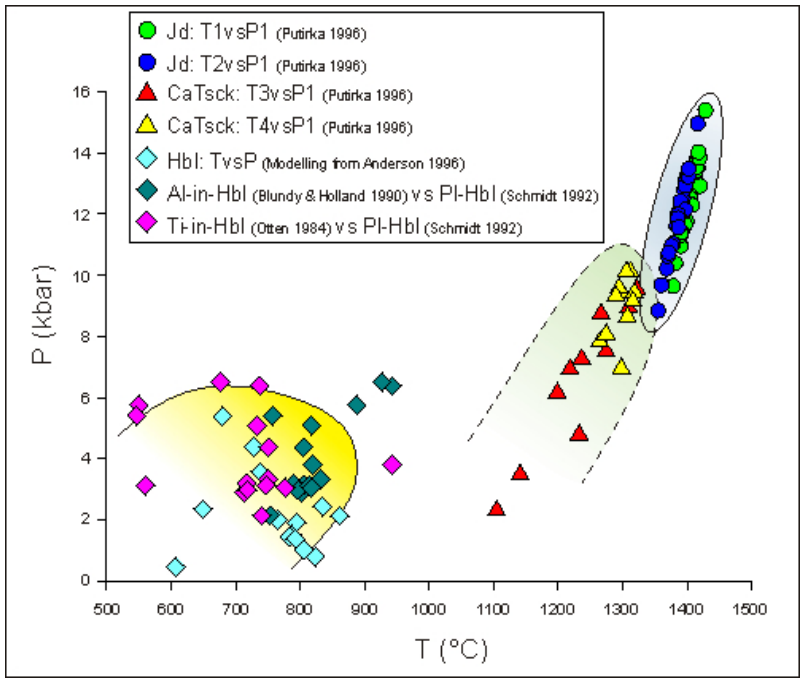

Figure 1. Jadeite (circle) vs Ca-Tschermak (triangle) equilibria for relic Cpx-cores and Hbl-thermobarometry (diamonds) for magmatic amphibole clots.

All magmatics of the complex has been superimposed by a Chl-Ep-Tr/Act substitution on primary femic and albitization of feldspar system. This subsolidus assemblage is related to subsolvus reaction during post-magmatic hydrothermal conditions. The presence of localized Chl-Ep veins associated to quartz-pegmatitic microdykes confirm this hypothesis.

In Lucci et al. [2011] a preliminary hypothesis of a P-T path constraining of magma uprising from source/deep reservoir to Isadalu complex crustal chamber was presented. Here we use a wider mineral dataset to test this preliminary hypothesis.

Application of the Putirka equations [2008] to Cpx-compositions produced two major P-T clusters. The first one is related to Jd-DiHd equilibria and shows a convergence for 1370-1420°C at 10-14 kbar. The second cluster refers to specimens with positive values of a Tschermak component and produces a scattered distribution between 1210-1320°C and 6-10 kbar. The Tschermak samples also produced a tail at 1100-1200°C for 2-4kbar. Tschermak scattered presence are in accordance with observations [Carmichael et al.,

1970] for melt with silica oversaturation and anorthitic plagioclase. Lower P values for Tschermak rules are also in accordance with experiments of Wikstrom [1970] who demonstrated the enrichment of CaAl2SiO6 in respect of Jd-Di for decreasing pressures.

We were then able to calculate the P-T conditions for formation of Hbl-amphibole through the application of Ti-in Hbl thermometry [Otten, 1984], Al-in-Hbl thermometry [Blundy and Holland, 1990], and Pl-Hbl barometry [Schmidt, 1992].

The comparison of different P-T models, applied on 13eCNK, Average Fe3+, and on 23 O,OH,F base recalculated amphiboles, shows a principal distribution at 700-850°C at 2-5 kbar in a major scattered window of 550-950°C and 1-6.5 kbar.

Could the disequilibrium between Jd and Tschermak molecula represent two distinct phases of the magma history? Could Jd content represent the P-T conditions of melt extraction from the source? Could Tschermak component, instead, be the pristine CA basic melt extracted from the source? Could hornblende P-T values indicate the conditions at which hydration of melts happened in Isadalu magma chamber?

Despite the absence of olivine or orthopyroxene, the enrichment of high compatible elements such as Ni+Cr+V (332 ppm in andesite and 394 ppm in shoshonite) and the recognize of Al-Cr-Spinel (Cr# in 45-55%) encored in amphiboles and in major ulvospinels support the idea of a deep melt extracted from a fertile mafic source [Arai, 1992].

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Spatial-temporal b value variations at Mt. Etna as a long-term precursor of volcanic activity

Ambra Mantovani[1,2], Maria S. Barbano[1], Salvatore D'Amico[2]

[1]*Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Catania, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*

Mount Etna is one of the largest and most active volcanoes in the world. It is located in the central portion of eastern Sicily at the intersection of two major regional active faults, the Ibleo-Maltese Escarpment and the alignment Messina-Fiumefreddo.

Following the idea suggested by Wiemer and Benoit [1996], we used the catalog of Mt. Etna earthquakes in the period 1997-2011, in order to investigate spatial-temporal b value variations of the Gutenberg-Richter law [Gutenberg and Richter, 1944] to identify any correlation with the volcanic activity.

Dataset contains 5654 events, acquired from the Permanent Seismic Network of Mt. Etna and located above7 km b.s.l., whose duration magnitude ranges from 1.0 to 4.4 [Gruppo Analisi Dati Sismici, 2012]. Because the completeness magnitude (Mc) changes over time, its variations were analyzed using a moving window. The analysis shows that the Mc decreases from 1997 to 2011, thanks to the improvements of the seismic network; this trend is interrupted from 2001 to 2003 because of the two pre-eruptive seismic swarms of July, 13-17/2001 and October, 27-29/2002. To evaluate b value variations, different Mc value thresholds were considered for the following periods:

- Mc = 2.0 from January 1997 to March 2001;
- Mc = 2.5 from April 2001 to December 2003;
- Mc = 1.5 from January 2004 to December 2011.

During the whole time span the b value shows values ranging from 0.8 to 1.4. Starting from 1997 till the mid of the same year, an increase of the b value is observed, and then it decreases and remains around values equal to about 1.0 until the beginning of 2001. The pre-eruptive seismic swarms of July 2001 and of October 2002 are responsible for the increasing of the b value, pointed out just before the start of the 2001 and 2002-2003 eruptions, respectively. Following the 2002-2003 eruption the b value decreases again, reaching minimum values between 2004-2005. Since 2006, two periods of the b value increasing have been noticed: the first between 2006 and 2008, and the second from the second half of 2009 and may be considered still unfinished at the end of 2011.

The spatial distribution of the results shows that, from 1997 to March 2001, high b values are located in the upper south-eastern flank, below the Summit Craters, extending toward east into the Valle del Bove. Between 2001 and 2003 high b values are observed in the eastern flank of the volcano, where most of the seismicity is concentrated. Since 2004 until 2011, high b values are confined in the southern and eastern flank of Summit Craters, in an area comparable to that noted for the first time span.

The temporal variations of the b value were also compared with volcanic observations and geophysical data [Allard et al., 2006; Bonaccorso et al., 2011; Bonforte et al., 2008], for better understand their meaning. The comparison shows that there is a good agreement between b value variations and inflation/deflation cycles; in particular, b value increases during the recharging phases of the feeding system, while during periods of deflation it decreases gradually. In conclusion, because the b value do not changes immediately before eruptive phases, its variations seem to be more efficient as a long term precursor of the volcanic activity and also a good indicator of the state of the volcano.

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The 1669 Monti Rossi eruption at Mt. Etna Volcano (Italy)

Maurizio Mulas[1], Daniele Andronico[2], Filippo Mundula[1], Raffaello Cioni[1,3]

[1]*Università di Cagliari, Dipartimento di Scienze Chimiche e Geologiche, Cagliari, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Italy*

Heralded by 14 days of intense seismic activity, early in the morning of 11 March 1669 a new eruption started on the south flank of Mt. Etna, in Sicily (Italy), signaled by the opening of NS-aligned eruptive fissures between 2800 and 850 m a.s.l. The 1669 eruption, lasted from 11 March to 11 July, represents the most powerful flank event of Etna in historical times. It was characterized by contemporaneous explosive and effusive activity during the first three months, and only lava flow output in the last month. A new large cone named "Monti Rossi" grew up to 158 m of height close to the lower tip of the eruptive fissures, while a prolonged effusive activity caused the formation of copious lava flows. The lava flows descended the volcanic slopes for more than 15 km, destroying several villages and the western portion of the town of Catania before reaching the coastline and entering into the sea for 1 km.

In the last years great attention has been turned on the study of the effusive activity and lava deposits of Monti Rossi eruption (MRE) [e.g., Corsaro et al., 1996; Crisci et al., 2003] mainly due to the important implications in terms of volcanic hazard from lava flow invasion. Conversely, the only reference study on the pyroclastic deposits of MRE date back to about 40 years [Walker, 1975].

In this paper, we try to fill the lacking of informations on the 1669 explosive activity presenting new data on: i) the eruption timing, ii) the tephro-stratigraphy of the eruptive sequence, and iii) the sedimentological, physical and compositional characterization of the pyroclastic products.

A research and analysis of the historical sources was preliminary carried out in order to identify possible eruptive precursors and to reconstruct in detail the chronology of the eruptive activity. Several campaigns were conducted, allowing us to find and describe 36 stratigraphic sections on the cone and up to 8 km of distance from the eruptive centers. Nineteen samples of tephra related to the fallout deposit were collected and studied in detail.

Figure 1. "La Piscina" reference section: a) A general view of the fall-out sequence; b) The first half of the fallout deposits with the first three subunits; c) The following primary fall deposits with interbedded the grain-flow deposits.

By tephro-stratigraphic studies we reconstructed the pyroclastic fallout sequence, defining 4 main units (A, B, C and D - Figure1) and tracing the dispersal of the main tephra-deposits. The mapping of the Monti Rossi cone, within which 2 main eruptive vents are recognizable (S-vent and N-vent), allowed us to understand the geology, the structural features and the stratigraphy of the deposits that formed the cone itself, and to correlate the phases of cone growth with the tephro-stratigraphic units of the fallout deposits.

Textural (grain-size, morphology, componentry), density and petro-compositional analyses, suggest a variation with time of the main physical and chemical features, although the compositions of all the analyzed products fall in the trachy-basaltic field. The characteristics of the pyroclastic sequences and associated tephra allowed us to subdivide the eruption into 3 main eruptive phases. They were characterized by the presence of different explosive styles from lava fountain (dominating the first phase) to Strombolian (prevalent during the last phase). The phreato-magmatic signature of products from a few stratigraphic units testified for the occurrence of magma-water interaction during the intermediate phase.

The total volume of the fallout deposit has been estimated to 4.22 x 10^7 m3, which totals to 8.02 x 10^7 m3 including the Monti Rossi cone. The latter value provides a mass eruption rate of 1.41-2.11 x 10^6 kg/s for the first 2-3 eruption days, in agreement with an eruption column height ranging between 5 and 7 km. The tephro-stratigraphic correlations support that at least 60 % of the Monti Rossi cone formed during the first days of activity. Finally, data on the dispersal and fragmentation of the fallout deposits classify both the whole 1669 eruption and the main eruptive units between the fields of the violent Strombolian and sub-Plinian eruptions.

The results obtained from this study, especially the tephro-stratigraphic reconstruction of the Monti Rossi eruption and the definition of the eruptive scenario for the first days of activity, can improve the hazard scenarios in case of highly explosive flank eruptions on the mostly urbanized slopes of Etna.

What do cicirara lavas tell at Mt. Etna? A complex tale of long magma storage, ascent and relationships with volcano-tectonics

Eugenio Nicotra[1,2] and Marco Viccaro[2]

[1]*Università della Calabria, Dipartimento di Scienze della Terra, Arcavacata di Rende, Italy*
[2]*Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Catania, Italy*

At Mt. Etna, the emission of plagioclase megacryst-bearing lavas, locally known as cicirara, has been linked with unusual eruptive scenarios [Nicotra and Viccaro, 2012a]. These highly porphyritic lavas were erupted during the final phases of the Ellittico Volcano (14-16 ka), when a summit caldera 4.5-km-wide formed, and during the XVII century, when long-lasting effusive events occurred. This last eruptive period, during which ca. 3 km3 of porphyritic lavas were emitted, culminated with the catastrophic 1669 AD event, during which a summit caldera formed [ca. 2500 m a.s.l.; von Waltershausen, 1880].

We attempted to relate the variation of the geometry of the shallow portion of the Etnean feeding system that allowed the formation of the large plagioclase crystals (up to 1.5 cm) with volcano-tectonics, namely magma ascent dynamics, eruption and caldera-forming events. Selected plagioclase megacrysts of the final phase of the Ellittico and the XVII century were investigated through high-resolution BSE images and core-to-rim profiles for An% and FeO wt%. This approach, which recently provided key information on the feeding system and ascent dynamics at Mt. Etna for mildly porphyritic lavas [Viccaro et al., 2010; Nicotra and Viccaro, 2012b], showed the occurrence of peculiar textures affecting the larger crystals (>7 mm). These megacrysts are characterized by patchy zoning at the core, followed by oscillatory-zoned envelopes. By contrast, crystals with size 1-7 mm display coarse sieve-textures at the core followed by oscillatory-zoning toward the rim. The most frequent texture is oscillatory-zoning, which is recorded by crystals of the dimensional class <7 mm. No skeletal textures, which are indicative of fast growth at high undercooling rate, were found for all the dimensional classes. Three types of oscillation, which are characterized by different wavelength and frequency of An content, were observed. These were related to small variation in chemical composition of the crystallizing melt and/or small variations of the physical parameters of the system. Patchy zoning provides important indications on the styles of magma ascent between the plagioclase nucleation threshold and the volatile saturation depth (~6 km beneath the summit craters), suggesting limited ascent rate in the deep levels of the plumbing system. At shallower levels, ascent might be faster as testified by crystals smaller in size affected by coarse sieve-textures. Conversely, oscillatory zoning and the other textures give information on the magma evolutionary processes during storage at shallow, saturated levels (above 6 km of depth). Stripes of melt/fluid inclusions and sieve-textures toward the rim are indication that other physical and chemical perturbations occur at shallow levels. Stripes of melt inclusions can be associated with steps of magma ascent coupled with volatile loss, whereas layers of fluid inclusions may be related to episodes of volatile flushing in the residing system. Strongly sieve-textured envelopes with An increase and constant FeO (found exclusively in lavas of the XVII century) may be related to mixing with magma similar in composition but more volatile-rich.

The appearance of "cicirara" lavas in some specific periods of the Etnean volcanic record is evidence that the plumbing system structure underwent progressive coalescence of its usual complex network of dykes and sills, as a response of increasing magma supply rate from depth that finally led to a large, shallow reservoir. This is also confirmed by the eruptive mechanisms of the XVII century events, when all lavas were poured out from fracture systems radial to the summit craters and located between 2,000 and 2,500 m on the volcano flanks (with the exception of the 1669 AD eruption, developed between 2,900 and 800 m and erupting from its lowermost tip). These features are interpreted as due to overpressure of the magmatic column within the central conduit. Huge amounts of magma withdrawal during long-lasting, purely effusive eruptions from this shallow reservoir may be linked to episodes of summit instability that caused major caldera collapses at Mt. Etna in the past (ca. 15-16 ka and during the XVII century).

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Tracking feeding system processes and magma transfer dynamics during the 2006 eruptive events at Mt. Etna Volcano

Eugenio Nicotra[1,2] and Marco Viccaro[1]

[1]*Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Catania, Italy*
[2]*Università della Calabria, Dipartimento di Scienze della Terra, Arcavacata di Rende, Italy*

The 2006 eruption at Mount Etna occurred after the long-lasting effusive activity of 2004-05. In contrast to the previous episodes, the volcanic phenomena displayed a variety of styles, from purely effusive to highly explosive. The 2006 episodes were therefore chosen among the eruptions characterizing the recent Etnean volcanic activity to verify the validity of an integrated study carried out on both whole rock and textural-compositional features of plagioclase crystals (Nicotra and Viccaro, 2012). Our aim is the understanding of magma dynamics at depth and of their correlation with volcanic activity at the surface. Major oxides, trace elements and Sr-Pb isotope ratios obtained on the bulk rock, coupled with the time-related changes of the textural distribution observed in plagioclase, were also correlated with the CO2/SO2 molar ratio of volcanic gases from real-time monitoring (data from Aiuppa et al., 2007). The control of the CO2/SO2 molar ratio throughout the eruptive period constitutes the best way to support and validate our results.

Volcanic products of the 2006 eruption are mesophyric K-trachybasalts with porphyritic index between 20 and 35. Their mineral assemblage is generally made up of phenocrysts of plagioclase (15-20 vol%), augitic clinopyroxene (10-15 vol%), olivine (2-5 vol%) and 1-3 vol% opaque oxides. Groundmass textures are variable from cryptocrystalline to holocrystalline, with intersertal textures as the most frequent. Microlites are mainly composed of plagioclase and subordinate augitic clinopyroxene, opaque oxide and olivine. Concerning the plagioclase crystals, four main textures were recognized at the core and rim, which indicate either near-equilibrium crystallization or disequilibrium accompanied by strong destabilization. These textures were attributed to: 1) crystallization near equilibrium conditions at depth or within the open-conduit (two types of oscillatory zoning), 2) magma decompression at variable ascent rates (coarsely sieve-textures and dissolution at the core), 3) inputs of more basic magma (sieve-textured rims). The major element variation through time suggests the involvement of a more basic magma, because MgO/FeOtot and CaO/Al2O3 ratios tend to increase from the beginning to the end of the eruption. This more basic magma was characterized by a peculiar geochemical and isotopic signature. This is testified by the negative trend of LREEs, some HFSEs (e.g., Nb, Zr, Y) and lead isotopes, together with increase of some incompatible element ratios (e.g., Rb/La, Zr/Nb) with respect to products erupted before.

All the available data, coupled with the CO2/SO2 molar ratio measured in the gas plume, support the idea that the pulsating regime observed for the volcanic phenomena at the surface during the period July-December 2006 reflects the transient, rapid ascent of several CO2 bubble fluxes and/or CO2-rich magma batches from the deep to the shallow levels of the plumbing system. We recognized at least two main phases throughout the 2006 eruptive period. A first phase (July 15 - October 21) during which de-hydrated magma already occupying the open-conduit system since March 2005 was drained through fracture systems related to the South East Crater. This first phase was probably triggered by a major recharging episode that occurred between July 8 and 14. Petrological data support the idea that a major input of magma characterized by a distinct geochemical-isotopic signature entered into the plumbing system and started to be erupted since October 23. This magma was also CO2-rich, as testified by the marked CO2/SO2 peak registered shortly before its emission. During the following weeks, other recharges of CO2 bubbles and/or CO2-rich magma batches were tracked, although of minor amount. The presence of this CO2-rich magma in the plumbing system strongly influenced the second phase of the eruption for what concerns the volcanic behaviour at the surface.

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Non-permanent and permanent GPS networks on the Ischia island: ground deformation between 1998 and 2012

Francesco Obrizzo, Prospero De Martino, Umberto Tammaro, Vincenzo Sepe, Elena Cubellis, Giuseppe Brandi, Mario Dolce, Andrea D'Alessandro, Santa Malaspina

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Italy

To improve the assessment of the ground deformation field at Ischia island, a non-permanent network of 20 GPS stations was established since October 1996. Successively the configuration network has changed significantly, new stations have been installed and some stations have been lost for various reasons. During 2003, the GPS network of Ischia has been integrated into NVAGN (Neapolitan Volcanic Area Geodetic Network), the non-permanent GPS network for monitoring the Neapolitan volcanic area.
The continuous monitoring highly improves the accuracy of site velocity estimations by the analysis of long time series of GPS observations [Riguzzi et al., 2011]. Therefore, three permanent GPS stations (AQMO, FORI, SERR) have been installed during 2001 [De Martino et al., 2011; Bottiglieri et al., 2010], a fourth permanent station (OSCM) has been installed in 2011. The Figure 1 shows the nonpermanent GPS network and the four permanent stations installed at Ischia island.
The results of the processing in terms of coordinates, velocities and time series are referred to the IGS05 absolute reference system, this implies that the planimetric components are dominated by the motion of the Eurasian plate, estimated at about 2.5 cm/year in NE direction.
Ischia is an island of a few tens of km2, therefore, to highlight the deformation of volcanic origin, is necessary to use a local reference, stable and outside the volcanic area. We have choosed the ENAV station, located on the rocks of the Sorrentino Peninsula, because it has used as a local reference by NeVoCGPS, the permanent GPS network for monitoring of Neapolitan volcanic area.
The ENAV planimetric velocities (Vnord = 16.5 mm/yr; Vest = 21.3 mm/yr) have been used to detrend GPS time series of permanent stations at Ischia and those obtained from processing of surveys in order to calculate a planimetric velocity field on the island.
In this paper we show the planimetric and the vertical velocity of the 23 sites measured in the 5 GPS surveys between 1998 and 2010 and of the four permanent GPS stations.

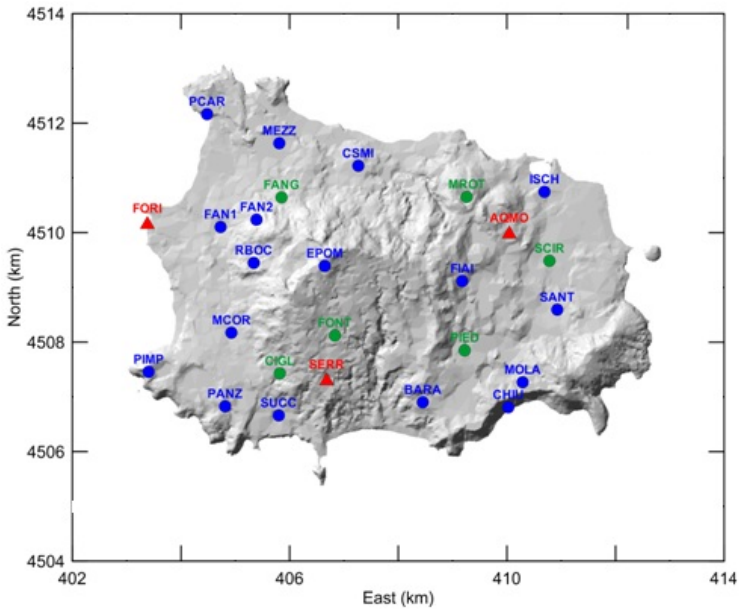

Figure 1. Permanent and non-permanent GPS stations on the Ischia island. The blu dots indicate non-permanent stations; green dots are stations not longer measured because damaged. The red triangles indicate the three permanent GPS stations of the NeVoCGPS.

In this time interval the dynamics of the island has been characterized by a significantly different behavior between the east and the west-central areas. All the GPS stations show a general subsidence and those most affected by the phenomenon are located in the south-central and north-west part of the island [De Martino et al., 2011, Obrizzo et al., 2011]. The subsidence in the eastern sector of the island has values greater respect to the north-west area. Southern sector shows significant subsidence rate too.
The EPOM station, located on the summit of Mount Epomeo, shows a significant subsidence velocity equal to -8.4 ± 1.0 mm/year in the period 1998-2010 [De Martino et al., 2011, Obrizzo et al., 2011], which could be a good indicator of the intense subsidence that involves the whole structure of M. Epomeo. The planimetric velocity field shows a different trend in the eastern sector of the island respect to the

center-west sector. In the eastern part of the island, the displacements are directed primarily toward west, while in the central area towards north.

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Clinopyroxene compositions as an indicator of magmatic water content: insight from high pressure experiments on trachybasaltic magmas

Cristina Perinelli[1], Mario Gaeta[2], Danilo Mauro Palladino[2], Pietro Armienti[1]

[1]*Università di Pisa, Dipartimento di Scienze della Terra, Pisa, Italy*
[2]*Università degli Studi La Sapienza, Dipartimento di Scienze della Terra, Roma, Italy*

Water contents in magmas affect liquidus temperatures, crystal fractionation trends, melt rheology and, in turn, the dynamics of ascent and eruption of magmas. Hence, it is of broad interest to determine the initial concentration of water in magmas and its variations during magma ascent and differentiation. Analysis of melt inclusions and experimental studies allowed to define the qualitative effects of water on magmatic processes; however, approaches for the quantitative estimation of water content in magmas are still scarce. In this regard, clinopyroxene (cpx) can be used as a tracer of crystallization processes since it is among the earliest and most abundant phase in basaltic rocks and contains the most complete record of crystallization history of a magma. In particular, since cpx abundances and compositions are controlled by magma water solubility, this phase has been successfully used as empirical hygrometer in trachybasaltic magmas of Mt. Etna [Armienti et al., 2011]. Experimental data available in literature on hydrous liquids representative of Mt. Etna volcanics, used to calibrate the empirical method, cover a wide range of pressure ($0.2 \leq P \leq 0.8$ GPa). However, very few runs were performed at high pressure ($P \geq 0.5$ GPa) up to now. For this reason, new HP experimental data on Etnean trachybasalts are fundamental for the implementation of the Cpx-hygrometer. Experiments were conducted in a piston-cylinder apparatus at a pressure of 0.8 GPa in the presence of 0-6 wt% of added H2O. Preliminary results indicate that cpx is the liquidus phase in both dry and hydrated conditions, followed by plagioclase and olivine. At a given temperature (e.g. 1150°C), the addition of 1 wt% of H2O produces a significant decrease of crystallization and appears also to influence the size and the number of crystals; the addition of 6 wt% of H2O induces nearly 100°C decrease of the liquidus temperature, down to about 1050°C. In terms of end-members (DiHd, EnFs, CaTs, Jd, CaTi), it appears that the main effect on clinopyroxene composition ascribable to an increase of water content in the melt is the increase of EnFs and Jd components coupled with a decrease of Ca-Tschermak end-member.

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The post-Minoan plumbing system dynamics at Santorini Volcano, Greece

Chiara M. Petrone[1], Lorella Francalanci[2], George E. Vougioukalakis[3], Laura Pinarelli[4]

[1]*Natural History Museum, Department of Earth Sciences, London, UK*
[2]*Universitá degli Studi di Firenze, Dipartimento di Scienze della Terra, Firenze, Italy*
[3]*I.G.M.E., Aharnes, Athens, Greece*
[4]*CNR, Istituto di Geoscienze e Georisorse, Sezione Firenze, Italy*

After the caldera-forming Minoan explosive eruption (3600 B.P.), the post-caldera islets of Palea- and Nea-Kameni formed, in the central part of the caldera, by nine eruptive events from 197 B.C until 1950 A.D. These events led to the emplacement of dacitic lava flows and domes also characterised by the presence of basalts to andesites magmatic enclaves, together with xenoliths of magmatic and metamorphic rocks. Mafic enclaves are commonly characterised by ellipsoidal or cuspate shape, with some chilled margins clearly suggesting their molten state at time of incorporation in the host magmas.

Dacitic rocks have low porphyritic index (4-17 vol%) which increases with time. Plagioclase is the prevalent mineral phase, followed by orthopyroxene, clinopyroxene, opaque minerals and apatite. Few resorbed xenocrysts of olivine with coronae of pyroxene are also present. Basaltic to andesitic mafic enclaves have variable texture ranging from cumulate to aphyric with common diktytaxitic textures and mineral phases similar to those of the dacitic host lavas. In some eruptive events, porphyritic enclaves with olivine in groundmass are also found.

Host lavas show a general decrease of the evolution degree with time, at the same time Mg# of pyroxenes and anorthite contents of plagioclase decrease. Lavas are characterised by higher La/Sm (3.4-4.5) than mafic enclaves suggesting clinopyroxene fractionation. Eu/Eu* and Tb/YbN values decrease from mafic enclaves to values less than unity shown by host lavas, clearly indicating plagioclase and apatite fractionations, respectively. Sr isotope ratios range from 0.70460 to 0.70480, and Nd isotope ratios from 0.51274 to 0.51265. Sr isotopes systematically increase toward the youngest lavas which are also the less evolved ones. Mafic enclaves, along with mineral separates, show slightly more Sr-radiogenic compositions in respect with host lavas, with the exception of the 46-47 A.D. products. Oxygen isotope ratios, determined in five eruptive events show a small range of variability (δ18O=+6.9-7.1). The highest oxygen ratios belong to the most evolved lavas, possibly suggesting a subtle correlation with the degree of evolution.

Our data indicate mixing/mingling processes between mafic and dacitic magmas. The increases in Sr isotope ratios with time and toward more mafic magmas suggest either crustal contamination by the mafic magmas or mantle source heterogeneities. Our data suggest the existence of a shallow layered reservoir where mixing/mingling processes take place at the interface between the upper dacitic and the lower mafic magmas. Cumulus processes and crystal fractionation, possibly accompanied by variable degree of crustal assimilation, also characterised the lower part of the plumbing system allowing further layering of the mafic magmas, generating the variable textures shown by the mafic enclaves. Type, composition and distribution of mafic enclaves change in different eruptions suggesting that different parts of the layered reservoir were frequently and variably sampled during time. This clearly points to multiple arrivals of mafic magmas during the post-Minoan activity of Santorini suggesting a still very active magma source, in good agreement with the 2011-2012 unrest phase at Santorini.

Heating experiments on 2010 Eyjafjallajökull ash: volcanological implications

Massimo Pompilio[1], Claudia D'Oriano[1], Camilla D'Eugenio[1],
Antonella Bertagnini[1], Raffaello Cioni[1,2]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Italy*
[2]*Università di Cagliari, Dipartimento Scienze Terra, Cagliari, Italy*

High temperature experiments were performed at atmospheric pressure on natural ash from Eyjafjallajökull Volcano in order to investigate the effects of reheating on morphological, textural and compositional features of clasts. Experiments are aimed at simulating the transformations of juvenile glassy fragments that, falling syneruptively into the crater or in the upper part of the volcanic conduit, are recycled by following explosions.

Starting material consists of tephra produced during continuous ash emission phases (May 2010) of the recent eruption.

Coarse glassy clasts were crushed in a nylon mortar in order to create an artificial ash, and then sieved to select the size interval of 1-0.71 mm. Ash clasts were put within sealed or open quartz tubes and suspended in a HT vertical furnace in order to prevent or to reproduce effects of air oxidation. The charge was kept at different temperatures above the glass transition (from 750 to 1047°C) for variable time (1-3 hours). Optical and electron microscope observations indicate that the high temperature and the exposure to the air induce large modifications on clast surfaces ranging from change in colour to extensive nucleation of vapor-phase minerals. Clasts also change in shape and show plastic deformation till sintering and welding. Re-heating promotes nucleation and growth of crystals in the groundmass and change of glass composition, sometimes associated with nucleation growth and coalescence of vesicles. Pore reduction and densification of the clasts occur at higher temperatures (>900°C).

Textural and compositional modifications observed in experimental charges have been compared with similar features detected in natural samples in order to identify general criteria to be used for discriminate between juvenile primary and recycled material and to make inferences on eruptive and magmatic processes.

The Mediterranean Supersite Volcanoes (MED-SUV) Project

Giuseppe Puglisi[1] and MED-SUV Team

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*

In response to the EC call ENV.2012.6.4-2 (Long-term monitoring experiments in geologically active regions of Europe prone to natural hazards: the Supersite concept - FP7-ENV-2012-two-stage) the INGV and a wide community of volcanological institutions proposed the project Mediterranean Supersite Volcanoes (MED-SUV), which is in the negotiation phase at the time of writing.

The Consortium is composed by 18 European University and research institutes, four Small or Medium Enterprises (SME) and two non-European University and research institutes.

MED-SUV will improve the consortium capacity of assessment of volcanic hazards in Supersites of Southern Italy by optimising and integrating existing and new observation/monitoring systems, by a breakthrough in understanding of volcanic processes and by increasing the effectiveness of the coordination between the scientific and end-user communities. More than 3 million of people are exposed to potential volcanic hazards in a large region in the Mediterranean Sea, where two among the largest European volcanic areas are located: Mt. Etna and Campi Flegrei/Vesuvius. This project will fully exploit the unique detailed long-term in-situ monitoring data sets available for these volcanoes and integrate with Earth Observation (EO) data, setting the basic tools for a significant step ahead in the discrimination of pre-, syn- and post-eruptive phases. The wide range of styles and intensities of volcanic phenomena observed on these volcanoes, which can be assumed as archetypes of 'closed conduit' and 'open conduit' volcano, together with the long-term multidisciplinary data sets give an exceptional opportunity to improve the understanding of a very wide spectrum of geo-hazards, as well as implementing and testing a large variety of innovative models of ground deformation and motion. Important impacts on the European industrial sector are expected, arising from a partnership integrating the scientific community and SMEs to implement together new observation/monitoring sensors/systems. Specific experiments and studies will be carried out to improve our understanding of the volcanic internal structure and dynamics, as well as to recognise signals related to impending unrest or eruption. Hazard quantitative assessment will benefit by the outcomes of these studies and by their integration into the cutting edge monitoring approaches thus leading to a step-change in hazard awareness and preparedness and leveraging the close relationship between scientists, SMEs, and end-users.

A revised stratigraphy of the pre-Green Tuff ignimbrites at Pantelleria (Sicily Channel)

Silvio G. Rotolo[1,2], Stephane Scaillet[3], Sonia La Felice[1], Grazia Vita-Scaillet[3]

[1]*Università di Palermo, Dipartimento Scienze della Terra e del Mare, Palermo, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy*
[3]*Institute des Sciences de la Terre d'Orléans INSU-CNRS, France*

Peralkaline silicic magmas were erupted at Pantelleria in a variety of eruptive typologies and magnitudes: pyroclastic flows, Plinian to strombolian pumice fallout and lava flows. The initial cycle (330-180 ka) was characterized mainly by effusive activity, and was followed by an intermediate cycle (181 - 85 ka), characterized by a clear drift to explosive activity. This period, onto we focus, is bracketed by six ignimbrite-forming eruptions (older and intermediate of the two caldera collapses at 140 and 50 ka that characterize the volcanological history of the island, which drained silicic and variably peralkaline magma for a cumulative volume close to 6 km3 DRE. These ignimbrites lack of continuity among the few outcrops (commonly in vertical scars) and also suffer from strong welding and rheomorphism. First reconstructions and correlations [Mahood and Hildreth, 1986], although still valid for many aspects, suffer from the poor precision of K/Ar ages, especially when Ar excess and xenocrystic contamination are common, as is the case for Pantelleria lavas and pyroclastic rocks. Recently, new correlations based on paleomagnetic methods [Speranza et al., 2012] succesfully identified and correlated two welded pyroclastic breccias outcropping in the NE and SW sectors of the island with the old caldera collapse, and also demonstrated the equivalence of two other ignimbrite units previously considered as separate eruptions.

Based on 14 new 40Ar/39Ar ages (laser heating on anorthoclase feldspar separates) ages and petrographic data, we propose an updated stratigraphy for the intermediate period and to provide accurate age brackets to the correlations. Recently, the application of 40Ar/39Ar methods on much younger (age < 20 ka) silicic lavas and tephra at Pantelleria [Scaillet et al., 2011], demonstrated highly precise and contributed to unravel the complex post-Green Tuff stratigraphy.

Our results can be summarized as follows:

- The pre-La Vecchia caldera eruptive history ended with the emplacement of two trachytic ignimbrites (at 181 ± 1.2 ka and 171 ± 1.7 ka), which were emplaced only in the south sector of the island. Both were truncated by the old (La Vecchia) caldera collapse.
- The age of the old caldera collapse is now tightly constrained between 139-146 ka , i.e. the new age of the welded pyroclastic breccia (previously undated). that represents the caldera-forming eruption [Speranza et al., 2012].
- After the La Vecchia caldera collapse, the first ignimbrite eruption occurred at 123 ka with a trachy-comenditic and crystal-rich unit emplaced in the NE to NW sectors of the island.
- At 107 ka a crystal-rich trachytic ignimbrite was erupted, together with some fines-rich lobes that (K/Ar ages) were previously considered as two different units, but with similar 40Ar/39Ar ages.
- Higher up in the stratigraphic sequence, two previously considered different ignimbrites (for an inferred volume of erupted magma close to 1.5 km3 DRE) demonstrated coeval by 40Ar/39Ar dating, and together are part of an eruptive paroxysm at 85 ka comparable in magnitude to the Plinian eruption of the Green Tuff (age 50 ka),
- The the recurrence time of the above mentioned eruptions, for a cumulative erupted magma volume close to 6 km3 DRE, suggest that at the end of the inter-eruptive period 85-50 ka the production and evolution rates of pantellerite magma peaked to reach a maximum peralkalinity.

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Type Minerals from the Island of Vulcano, Aeolian archipelago, Sicily, Italy

Massimo Russo[1] and Italo Campostrini[2]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Italy*
[2]*Università di Milano, Dipartimento di Chimica, Milano, Italy*

The Aeolian archipelago consists of seven islands of volcanic origin, arranged along an arc 90 km long that extends westward with other submerged volcanoes. The Vulcano Island is the southernmost and the third largest of these islands.

The island of Vulcano has an age of about 120,000 years. The volcanic activity occurred with many explosive eruptions some of which accompanied by caldera collapse. The last one led to the formation of the Fossa Caldera (or Lentia) where is located the still active vent of the island, La Fossa volcano, active since 6000 years at least.

The most recent eruptions, originated from La Fossa crater, except Vulcanello (183 b.C. - XVI century) and the two craters of Forgia Vecchia, which formed in the VI century A.D. and in 1727. The last eruption began on August 3rd, 1888 with a succession of explosions and lasted until 22nd March 1890. After 1890, there have been several cycles of increasing and decreasing fumarolic activity, the last of which began in 1977, reaching its peak in the early 90's with temperatures around 700°C, lowered to 400° - 450°C today. In recent years, fumaroles are concentrated on the northern rim and inside the crater.

Scientific interest in the island began in the late XVIII century, so that it became a destination for many travelling scientists including Déodat Gratet de Dolomieu, Jean Houel, who left us a beautiful series of paintings of Aeolian landscapes, and Lazzaro Spallanzani, then Giuseppe Mercalli, Ottorino De Fiore, Ludovico Sicardi and, among mineralogists, Geherard vom Rath, Alfonso Cossa, Ugo Panichi, Alfred Lacroix, Ferruccio Zambonini, Guido Carobbi and Carlo Garavelli.

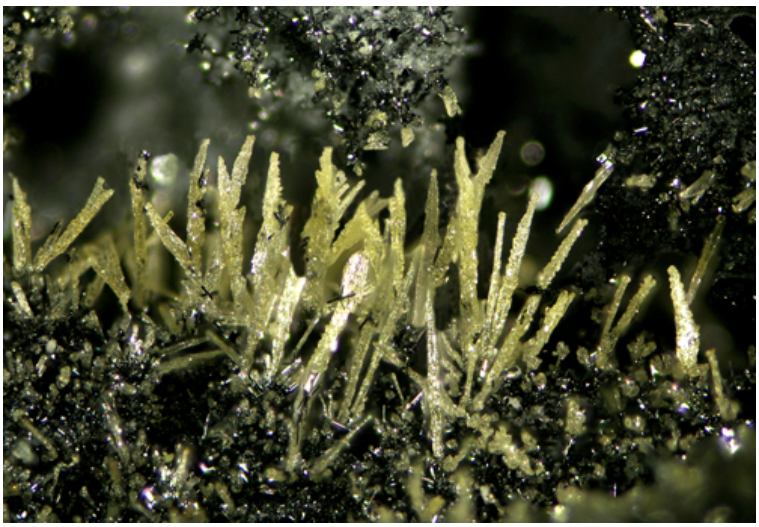

Figure 1. Hephaistosite, crystals of 3 mm, from La Fossa crater.

Currently the presence on the island of more than 100 mineral species is renowned. In addition, the Island of Vulcano is the "type locality" for 29 mineral species, 19 of which discovered in our studies. For the preliminary identification of mineralogical species a JEOL JSM 5500LV electron microscope (SEM), equipped with an EDS spectrometer has been used, For quantitative analysis a WDS JEOL8200 electron microprobe was used. Diffraction data were obtained using both a Philips PW1830 powder diffractometer and a Bruker APEX II single crystal diffractometer.

In 2011, the Associazione Micromineralogica Italiana published the book "Vulcano - Tre secoli di mineralogia", which describes all known species of this island [Campostrini et al. 2011]. The book is the result of a multi-year research project carried out thanks to a collaboration agreement between the Dipartimento di Chimica Strutturale e Stereochimica Inorganica (now Dipartimento di Chimica) of the University of Milan, and the Istituto Nazionale di Geofisica e Vulcanologia, sezione di Napoli-Osservatorio Vesuviano, aimed at the study of fumarolic minerals of Italian volcanoes.

Type Locality species on the island of Vulcano are the following.

- La Fossa crater: adranosite, adranosite-(Fe), aiolosite, argesite, barberiite, brontesite, cannizzarite, clinometaborite, cossaite, d'ansite-(Fe), demartinite, demicheleite-(Br), demicheleite-(Cl),

demicheleite-(I), hephaistosite, hieratite, knasibfite, lafossaite, lucabindiite, mozgovaite, panichite, pyracmonite, steropesite, thermessaite, thermessaite-(NH4), vurroite.

- Faraglioni: aluminocoquimbite, magnesioaubertite, millosevichite.

The studied minerals are essentially of fumarolic origin. Our research has focused on La Fossa crater rim and intracrater fumaroles, where temperatures range from 250°C to over 450°C, and the emitted gases are of magmatic origin, with SO2, H2S, HCl, HF forming sublimates at the vents. Other areas of research, not less interesting, were the Faraglioni of Levante and Vulcanello, where fumaroles have temperatures below 100°C and are rich in H2S (indicating geothermal or hydrothermal origin), allowing the deposition of sulphur and hydrate sulphates as a result of chemical attack of the rock by H2SO4.

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Architecture and 15 ka to present volcano-tectono-sedimentary evolution of the Neapolitan Yellow Tuff caldera offshore the Campi Flegrei, (Naples, Eastern Tyrrhenian Margin)

Marco Sacchi[1], Fabrizio Pepe[2], Marta Corradino[2], Donatella Insinga[1], Flavia Molisso[1], Silvio. G. Rotolo[2,3]

[1]*CNR, Istituto per l'Ambiente Marino Costiero, Napoli, Italy*
[2]*Università di Palermo, Dipartimento Scienze della Terra e del Mare, Palermo, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy*

The Campi Flegrei area is structurally dominated by the caldera associated with the eruption of the Neapolitan Yellow Tuff (NYT), a 40 km3 DRE ignimbrite dated at ca 15 ka BP [Deino et al., 2004], The volcanological evolution of the NYT caldera as been long described on the basis of outcrop and subsurface studies onland [Rosi & Sbrana, 1987; Orsi et al., 1996, and references therein; Di Vito et al., 1999; Perrotta et al., 2006; Fedele et al., 2011], but its offshore morphology, the stratal geometry of the volcaniclastic products and structures and the late-stage geodynamic evolution of the inner caldera resurgence are still poorly known.

We integrate geological and geophysical data obtained from high-resolution reflection seismic profiles (Sparker and Chirp sources) with gravity cores and swath bathymetry to better constrain the shallow structure and stratigraphic architecture and latest Quaternary to Holocene evolution of the submerged sector of the NYT caldera off the Pozzuoli Bay.

Our data clearly image, for the first time, the offshore geometry of the NYT caldera ring-fault zone, as well as the volcano-tectono-sedimentary evolution associated with the late stage evolution of the NYT inner caldera resurgence. Our interpretation suggests that since 15 ka the offshore sector of NYT inner caldera underwent significant deformation and uplift (with minor subsidence episodes) that occurred almost at the same rate as the post-glacial sea-level rise. Particularly, the inner Pozzuoli Bay started to deform soon after 15 ka BP, when the sea-level rise was initially faster than uplift. This caused a general increase of the accommodation space that was progressively filled up by volcaniclastic sediments. Since ca. 8 ka BP, along with the mid Holocene decrease in the rate of the sea-level rise, the early NYT resurgent structure was then uplifted up to the sea-level or even to partial subaerial exposure. From ca. 8 to 5 ka BP two distinct layers of resediments, mostly represented by density current deposits, separated by an interval of hemipelagic sediments. The two density flow units display a remarkable difference in their thickness and internal geometry. Across the bay, the lower unit is ca 5m thick in the western sector and reaches its maximum of ca 10 m in the central sector while it is absent towards the east. The upper unit, on the contrary, displays the minimum thickness of 10 m close to the central sector of the bay and increases up to ca 16 and 12 m in the western and eastern sector of the bay, respectively. The variation in thickness of the density flow deposits appears to be related with the amount of sediments available. The upper density flow deposits is also internally more chaotic respect to the lower one, suggesting higher energy and/or turbulence

A significant post 2 ka BP subsidence phase of ca 10 m is then recorded offshore Pozzuoli by the drowning of the infralittoral prograding wedge below the present-day fair-weather wave base. Sections clearly illustrate that the basin depocentre topography is not fixed at one position but migrates southwards in time.

We suggest that the uplift of the resurgent dome and subsidence of the southern sector, occurred after the eruption of the NYT, acted as a major control in the increase of the sea-floor gradient in the Pozzuoli bay. This may have triggered in turn, the deposition of gravity flow deposits along with a progressive migration of basin depocentres through time.

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The volcano-seismic clock of the South American Pacific Margin

Giancarlo Scalera

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Sismologia e Tettonofisica, Roma, Italy

A volcano-seismic correlation was for a long time suspected to occur for the Pacific margin events of South America. During his trip on the Beagle, Charles Darwin [1840, 1897] wrote about the eruptions associated to the Conception earthquake of 1835. Casertano [1963] survey following the 1960 great Chilean earthquake found some unclear evidence of a link between eruptions and the seismic event, while some reservations have been raised [Tazieff, 1962]. Scalera [2008] using the data available in 2006 in the Smithsonian Institution Catalogue of volcanic eruptions revealed grounded evidence that South-American Wadati-Benioff zone earthquakes with magnitude greater than 8.4 are associated to an enhanced rate of volcanic eruptions, but still was impossible to determine the causal chain between the two phenomena. An average return period of about 50 years was deducible from the data for the time window 1800-1999. After 2006, the Smithsonian Institution effort to improve our knowledge of this region has greatly increased the completeness of the catalogue adding the new eruptions for the 2000-2010 interval, but also adding a 50\% of new entries in the list of the Andean volcanoes. The occurrence of the Chilean Maule earthquake of 27 February 2010 (M=8.8), occurred at five decades from the 1960 one, has been the occasion to rework all the data in searching for additional clues able to indicate a preferred causal direction eruptions-earthquake or earthquake-eruptions or from a third more general cause (e.g. a mantle movements) to both eruptions and earthquakes. Finally, a possible synchronicity of the volcano-seismic correlation events with features of the Markowitz oscillation of the secular Polar Motion is investigated. If this synchronicity will be confirmed by comparison of a longer series of Polar Motion data and volcano-seismic events (average return period of 40-50 years), we would reasonably be in the presence of a phenomenon that puts in communication the Earth's surface with its deeper interior (core-mantle boundary; where the cause of the Markowitz oscillation is hypothesized to be located) and that should be directly linked to a slow asymmetrical expansion of the Earth.

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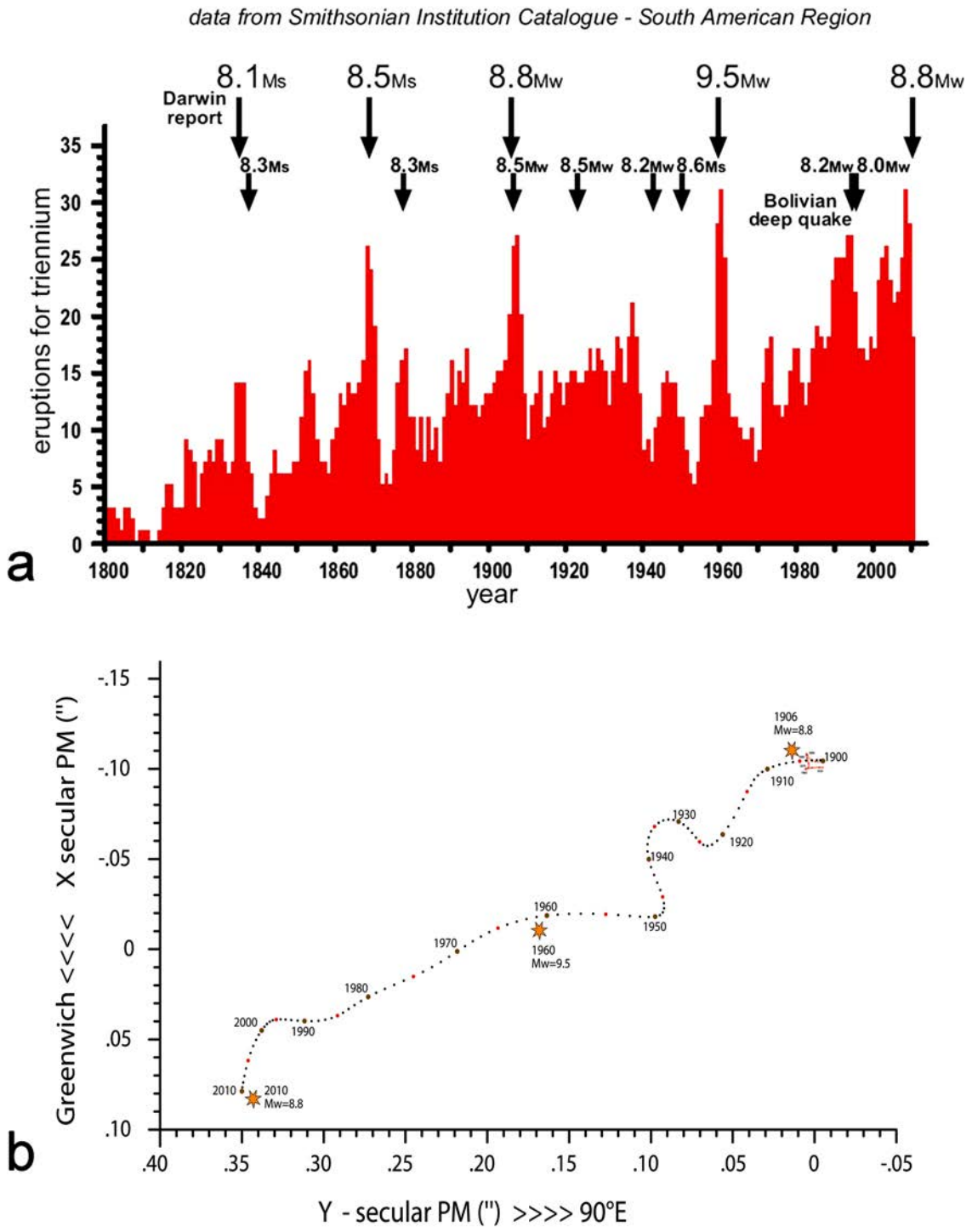

Figure 1. a) The triennial number of eruptions along the time axis. An enhanced rate of eruptions occurs in the occasion of great-magnitude earthquakes. b) Secular Polar Motion starting from 1846 and the volcano-seismic correlation events (stars).

Campi Flegrei unrest revisited: long term precursor to an eruption cluster?

Roberto Scandone and Lisetta Giacomelli

Università degli Studi Roma Tre, Dipartimento di Fisica, Roma, Italy

The record of seismicity, and deformation of Campi Flegrei is probably the longest in the world. Historical information of deformations dates back 2000 years. Early geodetic measurements of the sea-level in the Serapeum market were made in early 1800, and regular geodetic campaigns were made since early 1900. Historical information on earthquakes occurrence and damages are available since late 1400, and a local seismic network operated since 1970.

These data are complemented with detailed geological information on past activity and main geological events and offer a unique case among active volcanoes.

We revise the data of the last 2000 years to offer a new interpretation of the character of the past and present unrest. The small eruption of 1538 is the result of a recharge of a shallow magma chamber initiated in the early 1400, which depleted only a fraction of the intruded magma. The new intrusions, started in 1950, represent a continuation of the previous events, resulting in a net uplift of more than 10 meters with respect to the beginning of the recharge. The order of magnitude of the intrusion is in the same order as the one that preceded the peak of activity between 5000 and 3000 years ago, and may result in a similar cluster of eruptions.

Reduction of hazard from volcanic ash plumes between Sicily and Malta: the VAMOS SEGURO project

Simona Scollo[1], Francelle Azzopardi[2], Antonella Boselli[3,4], Mauro Coltelli[1], Raymond Ellul[2], Giuseppe Leto[5], Federico Messana[6], Gianluca Pisani[3,7], Michele Prestifilippo[1], Martin Saliba[2], Joseph Schiavone[8], Gaetano Spata[1], Nicola Spinelli[3,7], Xuan Wang[3,9]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Sezione di Catania, Catania, Italy*
[2]*University of Malta, Physics Department, Malta*
[3]*CNISM (Consorzio Interuniversitario per le Scienze Fisiche e della Materia), Roma, Italy*
[4]*IMAA-CNR, Potenza, Italy*
[5]*INAF - Osservatorio Astrofisico di Catania, Italy*
[6]*Comune di Montedoro, Caltanissetta, Italy*
[7]*Dipartimento di Scienze Fisiche, Università di Napoli "Federico II", Napoli, Italy*
[8]*Malta International Airport*
[9]*CNR-SPIN, Napoli, Italy*

Volcanic clouds disperse a great amount of volcanic ash into the atmosphere and constitute a major hazard to aviation and the local population. The accidental encounter between volcanic ash and airplanes causes damage to control surfaces, windshields and landing lights, loss of visibility and failure of critical navigational and operation instrumentations and in the worst scenario the failure of the engine. Moreover, volcanic ash deposited on the ground cause respiratory problems, eye injuries and skin irritations, damage to crops, roads and infrastructures.

Etna is one of the most active volcanoes in the world and during its frequent explosive episodes, eruption columns can rise to several kilometers above the summit craters and volcanic ash plumes may be dispersed into the atmosphere and reach as far as the Maltese islands. In order to reduce the impact that Etna's explosive activity has in the area between Sicily and Malta, a new research project VAMOS SEGURO (Volcanic Ash Monitoring and ForecaSting between Sicilia and Malta arEa and sharingG of the resUlts foR aviatiOn safety) has been funded by Programma di Cooperazione Transfrontaliera Italia-Malta 2007-2013, A1.2.3-62, Obiettivo Specifico 2.3).

In this project, new instruments have been installed at the University observatory facility at Giordan lighthouse and at Xewkija, Gozo. Moreover, an innovative Lidar system with scanning capability, designed and realized by CNISM (Consorzio Interuniversitario per le Scienze Fisiche della Materia) will be installed at two suitable sites will be able, one in Montedoro, Caltanissetta and another at Serra La Nave, 7 km away from the Etna summits will be located. Furthermore, an automatic forecasting system will produce simulations of the region affected by the volcanic ash plumes on a daily basis visible at www.ct.ingv.it/vamosseguro. The Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, lead partner of the project, together

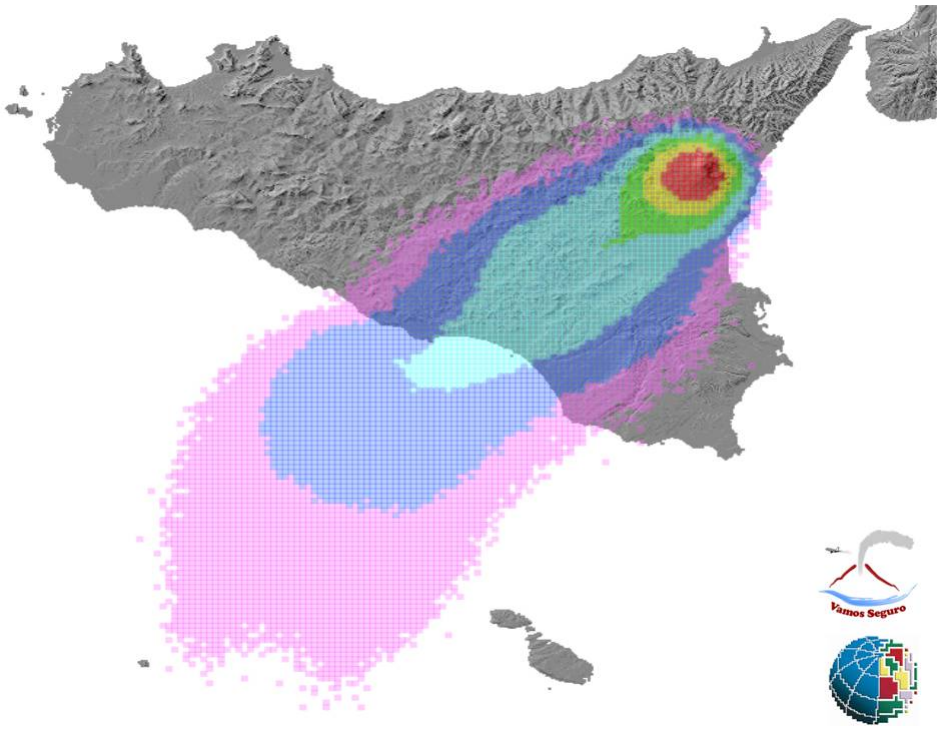

Figure 1. An example of volcanic ash forecasting between Sicily and Malta.

with the Istituto Nazionale di Astrofisica, Comune of Montedoro and the University of Malta, will provide actual measurements of ash and SO2 plumes and provide warnings to the competent Civil Authorities and Catania and Malta airports in the case of Etna eruptions.

A new scanning Lidar to monitor Etna volcanic plumes

Simona Scollo[1], Antonella Boselli[2,3], Mauro Coltelli[1], Giuseppe Leto[4], Giuseppe Passeggio[5], Gianluca Pisani[3,6], Nicola Spinelli[3,6], Xuan Wang[3,7]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Sezione di Catania, Italy*
[2]*IMAA-CNR, Potenza, Italy*
[3]*CNISM (Consorzio Interuniversitario per le Scienze Fisiche e della Materia), Roma, Italy*
[4]*INAF - Osservatorio Astrofisico di Catania, Catania, Italy*
[5]*INFN, Sezione di Napoli, Napoli, Italy*
[6]*Dipartimento di Scienze Fisiche, Università di Napoli "Federico II", Napoli, Italy*
[7]*CNR-SPIN, Napoli, Italy*

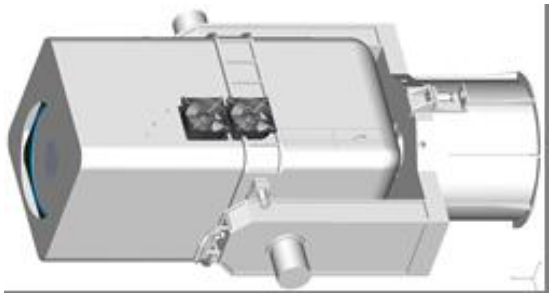

Figure 1. Lidar AMPLE funded by the VAMOS SEGURO project.

During explosive activity, volcanoes release a large amount of silicate particles and gases that are mainly made up of water vapor, carbon and sulphur dioxides. This emission represents the most important natural source of pollutants in the atmosphere, affects terrestrial ecosystems and human health on local to regional scales and influences microphysical processes in clouds and climate. Etna is one of the most active volcanoes in the world and is an extraordinary natural laboratory for studying both the contribution of volcanic activity to the atmosphere and dispersal and sedimentation processes during explosive eruptions. The Light Detection And Ranging technology (lidar) is an optical remote sensing technology that studies atmospheric composition, structure, clouds and aerosol. Lidar measurements allow investigating volcanic ash aerosol released during explosive eruptions and provided important information during the emergency of the Eyjafjallajokull eruption in April 2010. Lidar instruments are able to detect aerosol layers, and consequently estimate the column height with high precision and, if they have scanning capabilities, may give a 3D overview of volcanic plumes. The polarization lidar technique is also particularly suited to distinguish ash from liquid components in volcanic plumes. At Etna, a scanning lidar system was tested to analyze volcanic plumes. Data analysis allowed identifying the volcanic plume region and estimate ash mass concentration, distinguishing different types of aerosol, and may hence help differentiate ash-dominated from sulphate and/or water dominated plumes. A new scanning lidar has recently been set up by CNISM (Consorzio Nazionale Interuniversitario per le scienze fisiche e della material) and funded by the VAMOS SEGURO project, Programma di Cooperazione Transfrontaliera Italia-Malta 2007-2013, A1.2.3-62, Obiettivo Specifico 2.3, having the following features:

Wavelength: 1064 nm; 532 nm; 355 nm
Power: 1 W; 1.5 W; 0.6 W
Laser beam divergence: 0.5 mrad; 0.2 mrad; 0.3 mrad
Pulse width: 2 ns; < 2 ns; 1 ns
Laser repetition frequency: 1 Hz-1kHz; 1kHz; 1kHz

The Lidar installed at Montedoro, in Caltanissetta or at the Serra La Nave Observatory, only 7 km away from the Etna summit craters will considerably improve our understanding of the volcanic ash dispersal in the area between Sicily and Malta. This scanning lidar (Figure 1), used routinely during explosive eruptions, will drastically improve the monitoring of Etna volcanic plumes and help to reduce the risks to aviation operations during the frequent eruptions.

Inter-event Time Distribution of Mt. Etna's earthquakes

Simona Sicali[1,2], M. Serafina Barbano[1], Salvatore D'Amico[2], Raffaele Azzaro[2]

[1]*Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Catania, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*

The tectonic setting of Mt. Etna is commonly interpreted as due to the interaction of regional tectonics and local-scale volcano-related processes. Some authors [e.g. Bell and Kilburn, 2008; Traversa and Grasso, 2010] argued that in a volcano distinct seismogenic areas can be characterized by different patterns of interevent times (IETs). The IET is defined as the waiting time between two consecutive earthquakes, related to a specific period of time and a particular threshold of magnitude. The IET distribution of global or national catalogues is usually modelled using a gamma law [Corral, 2003]. This distribution is clearly different from the one for regional or local catalogues that have generally a bimodal shape originated from the mixing of the contribution of both correlated aftershocks (which have short interevent time) and independent events (which tend to be separated by longer time slot) [Naylor et al., 2010].

We analyzed the space-time IET distribution of Mt. Etna's earthquakes occurred between 1988-2011, using a magnitude threshold Md>2.5. We applied a dense network with node centres 2 km spaced from each other, creating a mobile grid to characterize contiguous and intermediate overlapping areas. To quantify the shape features for each IET distributions, we have computed some statistical parameters. The kurtosis k and the asymmetry A, have provided the measure of the "peakedness" of the distributions and an indication about the position of the peaks in relation with high or low time values, respectively. On the contrary, the aperiodicity a ($a = s/\mu$, where s is the standard deviation and μ is the mean) represents a way to estimate the regularity of earthquake occurrence over the time. By the analysis of the all IETs obtained for the Etna earthquakes vs the time, it appears evident that independent seismic events occur regularly (background seismicity), with waiting times of about 10^5 ÷ 10^6 s. Moreover, it is possible to observe interevent time classes of ~10^3 s correlated with seismic swarms. Since we recognized three different patterns of hypocenter distributions at Mt. Etna, a space-time analysis of the IETs has been performed by sub-grouping the earthquakes into three depth classes: 1) from the surface to 5 km b.s.l., 2) between 5 km and 12 km b.s.l. and 3) below 12 km b.s.l. By comparing the IET distribution patterns obtained in every node grid and the statistical parameter variations, we can identify some seismogenic levels with different earthquake recurrence time. The boundaries of the sectors with the similar IET distribution patterns are shown in the asymmetry map (Figure 1).

The IET analysis at Mt. Etna indicates the presence of a sector with prevalent "volcanic behaviour" (S1) and permits to distinguish it from the ones (S3, S4, S5 for z > 5 km) with a more "tectonic" behaviour

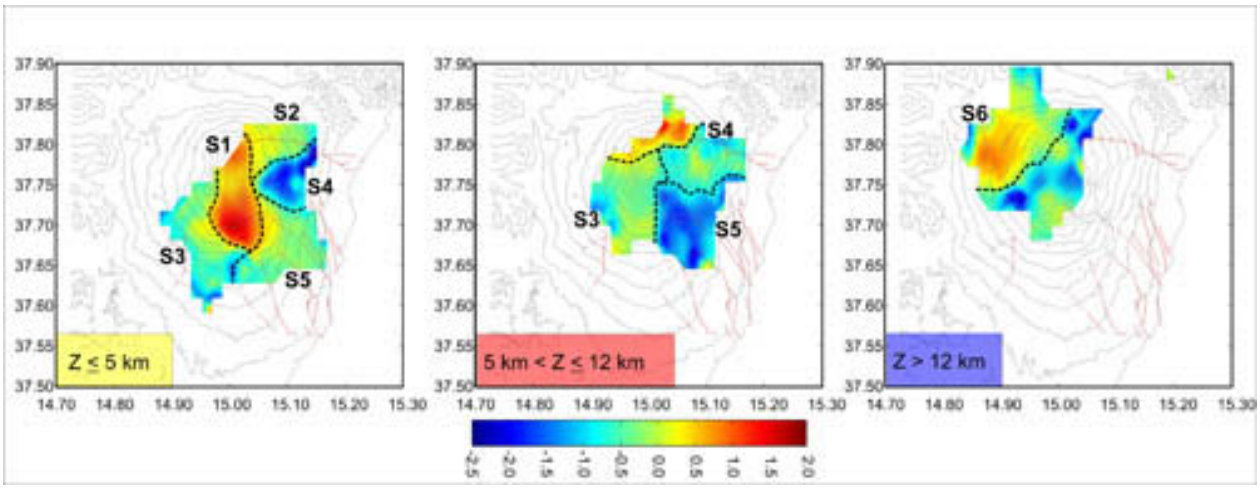

Figure 1. Map of the asymmetry of the IET distribution (colored scale) for three different depth (Z) levels. Dashed lines indicate sectors of the volcano showing the same IET distribution pattern.

[Bell and Kilburn, 2008], where the activation of seismogenic structures seems to be more related to the regional stress rather than factors due to volcanic processes. In addition, the IET distribution pattern of S2 suggests that in this sector volcanic and the tectonic regimes coexist, whereas S6 has a more complex behaviour and further analyses are required.

In conclusion, the temporal occurrence of earthquakes at Etna reflects the influence of regional tectonic regime on the volcanic processes; the space-time IET analysis could represent a tool to discriminate sectors affected by different stress fields.

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Seismicity distribution and stress field before the 2001 Etna eruption

Simona Sicali[1,2], Graziella Barberi[2], Ornella Cocina[2], Carla Musumeci[2], Domenico Patanè[2,3]

[1]*Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Catania, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[3]*Instituto Andaluz de Geofísica, Universidad de Granada, 18071 Granada*

At Mt. Etna, the 2001 lateral eruption represents one of the most investigated event both from a volcanological and geophysical point of view. The eruptive activity occurred from July 17th to August 9th, 2001 and was preceded by several days of intense seismicity and ground deformation. We investigated the seismic activity recorded during November 2000-June 2001 interval time preceding the eruption, to understand the meaning of the seismicity connected to the dike intrusion, that locally modified the stress field acting in the area.

The earthquakes were recorded by the permanent local networks operating during that time and run by the Istituto Internazionale di Vulcanologia (IIV-CNR) and the Sistema POSEIDON. During the analyzed period, 683 earthquakes have been firstly localized by means of a 1D velocity model derived from Hirn et al., 1991 using the software HypoEllipse [Lahr, 1989]. In order to further improve the quality of the seismic dataset, we extracted 522 earthquakes with Gap less than 200°, Erh < 1.5 km, Erz < 2 km, RMS less than 0.5 sec, and a minimum number of S phases equal to 2.

This latter seismic dataset was relocated using TomoDD code [Zhang and Thurber, 2003] and a 3D velocity model (Patanè et al., 2006 after modified).

Moreover, using first motion polarity data, 3D fault plane solutions were computed by means of the software FPFIT [Reasenberg and Oppenheimer, 1985]. Then, adopting restricted selection criteria (Npol more than 12; focal plane uncertainties less than 20°; number of solutions less or equal to 2; number of discrepancies less than 15%), we selected 111 FPSs (Figure 1). This dataset represented the input file for the stress and strain tensors computation using the inversion codes developed by Gephart and Forsyth [1984] and by Kostrov [1974], respectively.

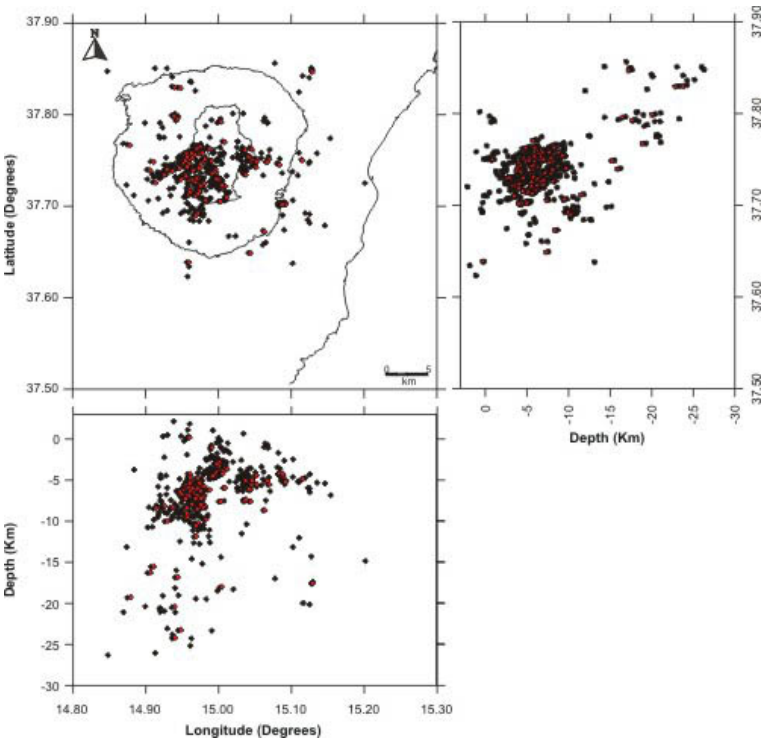

Figure 1. Epicentral map and vertical cross section of the 3D relocated seismicity (black circles) and of the 111 selected fault plane solutions used for stress inversion (red circles).

On the basis of the space-time distribution of the 3D relocated seismicity and of the stress tensor computation results we put some seismological constraints on the recharging phase leading to the 2001 eruption.

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Constraining timing of volcanic activity at Pantelleria (Strait of Sicily): the paleomagnetic contribution

Fabio Speranza[1], Silvio G. Rotolo[2], Patrizia Landi[3], Anita Di Chiara[1], Francesca D'Ajello Caracciolo[1], Alessandro Pignatelli[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione Geomagnetismo, Aeronomia e Geofisica Ambientale, Roma, Italy*
[2]*Università di Palermo, DipartimentoChimica e Fisica della Terra, Palermo, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Italy*

During the last few years, we carried out an extensive paleomagnetic investigation of lavas and welded ignimbrites exposed at Pantelleria (Strait of Sicily). For volcanics older than 10 ka (Holocene), the paleosecular variation (PSV) of the geomagnetic field "frozen" in the volcanic rocks just after eruption was used as correlative tool of scattered outcrops, with an estimated time resolution in the order of 100 years. Conversely, the PSV recorded by Holocene volcanics was also used to provide absolute dating, after comparison with reference geomagnetic field directions independently gathered by archeomagnetism and paleomagnetism of age-calibrated Holocene lacustrine cores from Europe.

Although oldest volcanics exposed at Pantelleria (Strait of Sicily) exceed 300 ka, most of the island is covered by the 45-50 ka Green Tuff ignimbrite, synchronous with formation of the Cinque Denti caldera, and younger lavas and scoria cones. Pre-50 ka volcanics (predominantly ignimbrites) are confined to isolated sea cliffs, and their stratigraphic-chronologic framework was still not completely resolved. Relying on volcanic stratigraphy and K/Ar dating [Mahood and Hildreth, 1986], it was previously proposed that collapse of older La Vecchia caldera was synchronous with ignimbrite Q (114 ka) emplacement, and that ignimbrites F, D, and Z (106, 94, and 79 ka, respectively) were subsequently erupted. We obtained paleomagnetic directions from 23 sites spread in the P (133 ka) and four younger ignimbrites, and from an uncorrelated (and loosely dated) welded breccia considered to represent the caldera-forming eruption [Speranza et al., 2012]. We found that ignimbrites D and Z correspond, in good agreement with recent Ar/Ar ages constraining to 87 ka the D/Z eruption. The welded breccia correlates with a thinner breccia lying below ignimbrite P at another locality, implying that collapse of La Vecchia caldera should be aged at ~130-160 ka. This caldera was subsequently filled by ignimbrites P, Q, F, and D/Z. Paleomagnetic data also showed that northern caldera margin underwent a ~10° WNW tilting after emplacement of ignimbrite P, indicating further caldera collapse after ignimbrite eruption.

Besides pre-Green Tuff ignimbrites, paleomagnetic investigation was also focused in the products of the most recent silicic eruptive cycle of Pantelleria [Speranza et al., 2010]. Previously radiometrically dated by K/Ar at 5-10 ka, our comparison with proxies for geomagnetic field directions allowed us to narrow considerably the time window during which these eruptions occurred. One of our sites was located in the Serra della Fastuca fall deposit, produced by the first explosive event of the eruptive cycle. The other nine sites were located in the most recent explosive (pumice fall and agglutinate from Cuddia del Gallo and Cuddia Randazzo) and effusive (Khaggiar lava) products. The (very similar) paleomagnetic directions gathered from eight internally consistent sites were compared to reference geomagnetic field directions of the last 5-10 ka. Directions from Cuddia del Gallo agglutinate and Khaggiar flows translated into 5.9-6.2 ka ages, whereas the Fastuca pumices yielded a slightly older age of 6.2-6.8 ka. Hence, the most recent silicic eruptive cycle lasted at most a millennium and as little as few centuries around 6.0 ka. Paleomagnetically inferred ages are in good agreement with published (and calibrated by us) 14C dates from paleosols/charcoals sampled below the studied volcanic units and with recent Ar/Ar ages [Scaillet et al., 2011], whereas previous K/Ar data are more scattered and yield ~30% older ages.

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Hazard assessment of far-range volcanic ash dispersal from a violent Strombolian eruption at Somma-Vesuvius Volcano, Naples, Italy: Implications on civil aviation

Roberto Sulpizio[1,2], Arnau Folch[3], Antonio Costa[4,5], Chiara Scaini[3], Pierfrancesco Dellino[1]

[1]*Università degli Studi di Bari "Aldo Moro", Dipartimento di Scienze della Terra e Geoambientali, Bari, Italy*
[2]*IDPA-CNR, Milano, Italy*
[3]*Barcelona Supercomputing Center – Centro Nacional de Supercomputación (BSC-CNS), Spain*
[4]*Environmental Systems Science Centre, University of Reading, Reading, UK*
[5]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Italy*

Long-range dispersal of volcanic ash can disrupt civil aviation over large areas, as occurred during the 2010 eruption of Eyjafjallajökull Volcano in Iceland. Here we assess the hazard on civil aviation posed by volcanic ash dispersal from a violent Strombolian eruption at Somma-Vesuvius, the most likely scenario in case of renewal activity at this volcano. This scenario is of concern for two main reasons: i) violent Strombolian eruptions have a high probability of occurrence (38%), being this type of event quite common in the most recent period of activity at Somma-Vesuvius (between AD 1631 and 1944) and, ii) violent Strombolian eruptions typically last longer than higher-magnitude events (from 3 to 7 days for the climactic phases) and, consequently, are likely to cause more prolonged air traffic disruption (even at far-range if a substantial amount of fine ash is produced as typical occurred during Vesuvius eruptions). We compute probabilistic hazard maps for airborne ash concentration at relevant flight levels using the FALL3D ash dispersal model and a statistically representative set of meteorological conditions. Probabilistic hazard maps are computed for two different ash concentration thresholds of 2 and 0.2 mg/m3, which correspond, respectively, to the no-fly and enhanced procedure conditions defined in Europe during the Eyjafjallajökull eruption. The seasonal influence is also analysed by computing seasonal maps. We define the persistence of ash in the atmosphere as the time a concentration threshold is exceeded divided by the total duration of the eruption (here the eruption phase producing a sustained eruption column). The maps of averaged persistence give additional information on the expected duration of the conditions leading to flight disruption at a given location. Our results assess the impact that a violent Strombolian eruption would have on the main airports and aerial corridors of the Central Mediterranean Area. In this light, results can help in devising procedures for minimising the impact posed by these long-lasting low-intensity volcanic events on civil aviation.

Insights on Segregation and Support Mechanisms of Granular Flows from Field Analysis and Laboratory Experiments

Roberto Sulpizio[1], Damiano Sarocchi[2], Roberto Bartali[2], Luis A. Rodriguez-Sedano[2]

[1]Università degli Studi di Bari "Aldo Moro", Dipartimento di Scienze della Terra e Geoambientali, Bari, Italy
[2]Instituto de Geología UASLP, San Luis Potosí, Mexico

Gravity-driven flows in volcanic areas comprise some of the most complex and hazardous natural phenomena, and can occur either during explosive eruptions or during volcanic quiescence. Among volcanic gravity-driven flows the study of those characterised by high-particle concentration is exceedingly important, since they encompass some of the most destructive volcanic phenomena. In all these phenomena the same basic forces govern motion, but differing mixture compositions, initial and boundary conditions yield varied dynamics and deposits. Examples range from dry rock avalanches, in which pore fluid may play a negligible role, to liquid-saturated debris flows and gas-charged pyroclastic density currents, in which fluids may enhance bulk mobility. Field studies on real volcanic gravity-driven deposits remain an irreplaceable tool for obtaining crucial information about their behaviour. This is because a volcanic gravity-driven deposit records the physical processes that occurred at time of deposition, and particle morphology and deposit texture can yield precious information about transportation regime. New insights on behaviour of granular flows come from combining field study on texture of block and ash flows, particle shapes and laboratory experiments carried out using a 3.5 m flume engineered at the Instituto de Geologia. The flume is equipped with different sets of sensors and the spreading area is bordered with glassy walls in order to observe the deposit aggradation. The experimental runs are carried out using real volcanic particles combined to form synthetic grain size distributions. First results highlight some fundamental processes in particle transportation and deposit aggradation that are compared with real deposits.

Non-stationary nature of SO2 degassing at Etna's North-east crater (Italy)

Giancarlo Tamburello[1], Alessandro Aiuppa[1,2], Andrew J. S. McGonigle[2,3], Andrea Cannata[4], Euripides P. Kantzas[3]

[1]*Università di Palermo, Dipartimento Scienze della Terra e del Mare, Palermo, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy*
[3]*University of Sheffield, Geography Department, UK*
[4]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*

Mount Etna is one of the most active basaltic volcanoes in the world, and one of the largest volcanic SO2 point sources to the atmosphere. Persistent passive SO2 plume emissions occur via the four main summit craters (North-East Crater, Voragine, Bocca Nuova and South-East Crater), which contribute to almost the totality of the emitted SO2. Additional emissions, which are sometime very vigorous, may temporary take place during flank eruptions. Visual observations indicate that the North-East Crater differs - as is the case for its degassing regime - from other vents, in that it is systematically associated with intermittent emissions of gas as clouds or puffs, typically spaced about tens of seconds from each other. This "puffing" behaviour is most evident when viewed from the rim of the crater: gas emission virtually stops between one puff and the next. No effort has ever been spent in the past to identify the high-frequency patterns of SO2 flux variation from the North-East crater, to relate them to the puffing behaviour observed at that vent, and to explore the source (conduit) mechanisms controlling this degassing behaviour. To fill this gap , we performed (from the 1st to the 4th of July 2011) a dedicated field campaign capturing germane SO2 flux data with a novel UV imaging technique of unprecedented sampling frequency (0.5 Hz). The gas flux modulations captured by our observations show remarkable temporal variability and, rather than having a single defined frequency, involve a band of frequencies in the 0.005-0.025 Hz range. We interpret this degassing behaviour to arise from the rhythmic ascent and surficial bursting of separate trains of gas bubbles, separated by wavelength values at the centimetre scale. We also suggest the observed time-changing gas flux characteristic periods to derive from a time-variable spacing of individual gas bubble layers, as an ultimate effect of heterogeneities in vesicularity and bubble dimension over the conduit height.

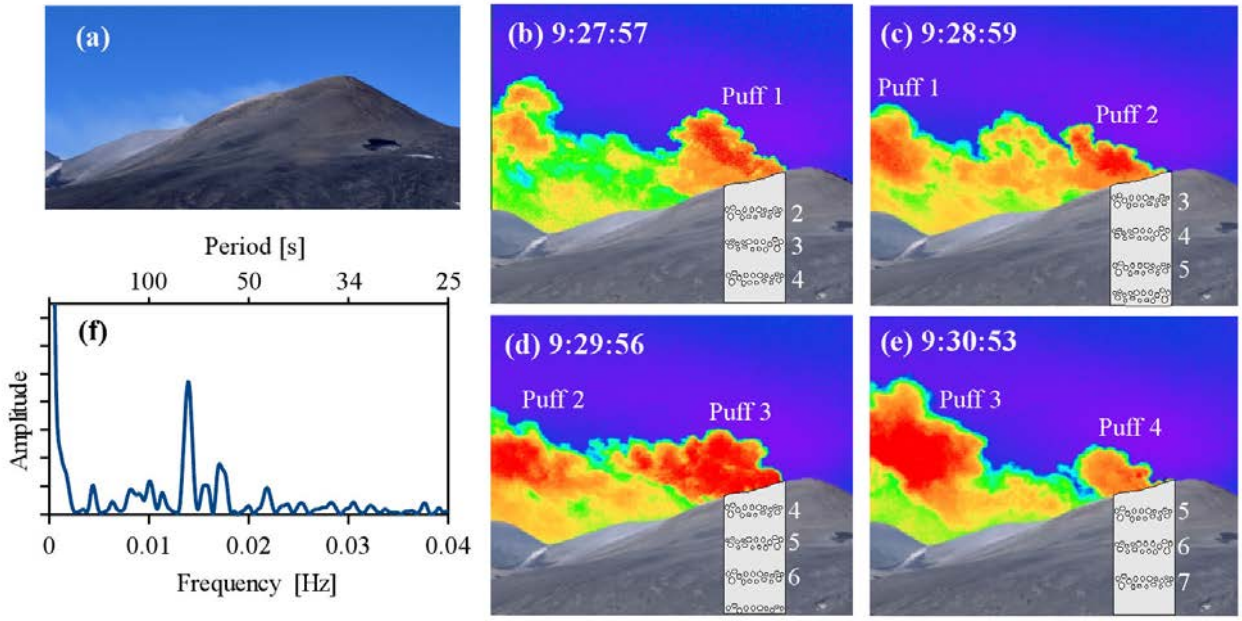

Figure 1. (a) View of the North-East crater from Pizzi Deneri measurement site on the NE flank of Mt. Etna. (b-e) Pseudo-colour images of plume SO2 column densities (in ppm·m). (f) FFT of the corresponding SO2 flux time series, showing a distinct ~77 s periodicity.

Archeomagnetic and 226Ra-230Th dating of Etna lavas in the framework of stratigraphic analysis: eruptions from the last 2400 years

Jean-Claude Tanguy[1], Michel Condomines[2], Stefano Branca[3], Santo La Delfa[4], Mauro Coltelli[3]

[1]*Institut de Physique du Globe de Paris and CNRS, Saint-Maur des Fossés cedex, France*
[2]*Université de Montpellier2 and CNRS, Montpellier cedex, France*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[4]*Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Catania, Italy*

The high-precision archeomagnetic method developed at St. Maur laboratory (IPGP), checked by 226Ra-230Th radioactive disequilibria (University of Montpellier), allows dating volcanic materials of Etna with an accuracy of tens to hundreds of years for the last two millennia. Many lava flows and eruptive fissure deposits are shown to have erupted during this period thanks to careful field investigations and stratigraphic data [Branca et al., 2011], although their precise ages were unknown, the historical documents being almost entirely lacking before the late Middle Ages. We have studied 24 of these volcanic units, including 301 large samples [see Tanguy et al. 2012]. In most cases our results allow attribution of ages during the last 2,400 years, except for two flows which are shown to be prehistoric, i.e. older than 750 BC (Figure 1).

Concerning the eruptive history of the investigated period, the oldest lava flow recognised is the one that reached the sea in 396 BC, cutting the way to the Carthaginian army (Diodorus). This is ascribed by us to the large lava field beneath the present Santa Tecla village, because it is the only flow reaching the sea at this epoch. Also, we dated at about 200 BC and 150 BC two large eruptions located in the south and southeast flanks, which generated the Monpilieri and Salto del Cane scoria cones. These two eruptions are probably those mentioned in 135 and 126 BC by Julius Obsequens. Then the 122 BC plinian event produced a summit caldera and huge damage in Catania. The 252 AD "St. Agata" lava flow is the only one clearly reported by an historical chronicle within the first millennium. This event necessarily corresponds to the Monpeloso scoria cone and its short flow which stopped well before Catania, as reported by the Bollandists. Two other large events, until now not reported, took place on the southeast flank at about 350 AD (S. Giovanni la Punta flow) and 450 (Piazza Sant'Alfio flow). From 450 to 1600, at least two dozens flows are identified, especially on the West flank, but several others took place all around the volcano, only six of which are mentioned in historical accounts.

We know that during the last 400 years one event occurred below 1000 m elevation, i.e. the 1669 eruption. However our reconstruction of the geochronological record of Etna flanks eruptions of the past 2,400 years evidence that numerous events took

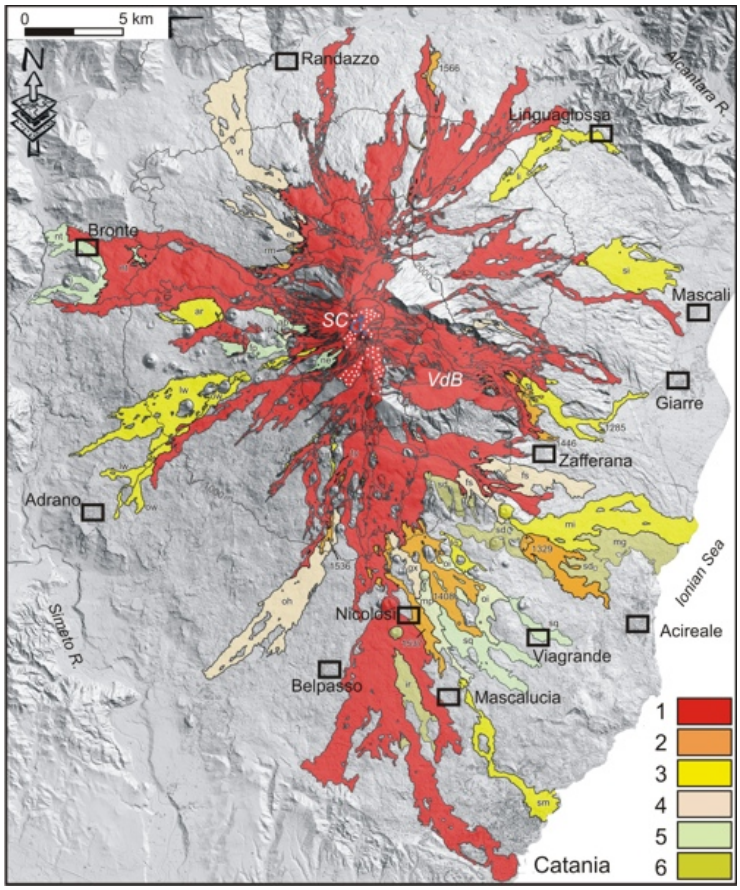

Figure 1. Sketch map of the volcanic products of Etna (after Tanguy et al., 2012) erupted during the past 2,400 years. 1) post-1600 AD lava flows and scoria cones; 2) 1300-1600 lavas; 3) 1000-1300 lavas; 4) 476 AD-1000 lavas; 5) 122 BC-476 AD lavas; 6) pre-122 BC lavas. The white spots indicate the recent pyroclastic cover of the summit area. The blue lines are the summit craters-rim SC; Valle del Bove = VdB.

place below 1000 m elevation (Figure 1). In particular, during the Middle Ages seven flank eruptions involved the lower east flank between c.a. 1000 and 1300 that is today the most densely inhabited region of Etna. Therefore, in terms of hazard assessment the occurrence of this type of low elevation flank eruptions must be considered in the future study of its the evaluation since they represent the highest destructive event expected for Etna Volcano. Finally, regarding the well-known eruptive history of the past 400 years we have completed the information reported in the recent catalogues with the recognition of two flank eruptions occurred around 1630 and 1850 in the upper northwest flank not reported in the historical sources.

As a conclusion we would point out that a multidisciplinary approach is necessary for reconstructing the eruptive history of a complex volcano such as Mount Etna. Although the historical written accounts can sometimes be quite useful, they usually present too many gaps and their interpretation is almost always insufficient for a clear identification of the lava flows and eruptive fissures. Such a problem of identification of the volcanic products is of vital importance not only for civil protection, but also for volcanological research, statistics of eruptions, volumes of magma output, petrological evolution, and so on.

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The effect of undercooling on the crystallization kinetics of Stromboli and Etna basalts at dynamic conditions

Alessandro Vona and Claudia Romano

Università degli Studi Roma Tre, Dipartimento di Scienze Geologiche, Roma, Italy

The number, size and shape of crystals in a rock reflect the relative kinetics of nucleation and growth, which are in turn dependent on the magma solidification history. Controlling the thermal history by experimental studies, a quantitative relationship between the solidification process and crystallization kinetics can be determined. Most experimental studies have focused their attention on the effect of cooling rates or undercooling on rock textures, nucleation rates and morphologies of crystals in static conditions. Despite the importance of flow (or convection) in defining the crystallization kinetics in magmas, no attempt has been made to examine and quantify this effect experimentally.

In this study we explore the effect of undercooling and stirring on the evolution of the texture and the crystallization kinetics of remelted basaltic material from Stromboli (pumice from the 15th March 2007 paroxysmal eruption) and Etna (1992 lava flow). Isothermal crystallization experiments were conducted at different degrees of undercooling and different applied strain rate (T=1157-1187 °C and strain rate = 4.26 s^-1 for Stromboli; T=1131-1182 °C and strain rate = 0.53 s^-1 for Etna). Melt viscosity increased due to decreasing temperature and increasing crystal content. The viscosity typically achieved a steady value after 10^4-10^5 s. The mineralogical assemblage comprises sp + plg (dominant) ± cpx with an overall crystal fraction between 0.06 and 0.27, increasing with undercooling and flow conditions.

Both degree of undercooling and deformation rate deeply affect the kinetic of the crystallization process. Plagioclase nucleation incubation time strongly decreases with increasing ΔT and flow, while slow diffusion-limited growth characterizes low ΔT-low deformation rate experiments. Stromboli (high strain rate) plagioclase growth rates G display relative small variation (10^-9 m s^-1), while a slight increase of G can be observed for plagioclase from Etna (low strain rate) with decreasing temperature, from (10^-10–10^-9 m s^-1). Plagioclase nucleation rates J continuously increase with undercooling from 10^7-10^8 m^-3 s^-1 for Stromboli. As for Etna, nucleation rate has an extremely low value of 9.2 x 10^4 m^-3 s^-1 at the lowest undercooling experiment (ΔT=20°C), indicating that the crystallization process is growth-dominated and that possible effects of textural coarsening occur. G values obtained in this paper are generally one or two order of magnitude higher compared to those obtained in literature for equivalent undercooling conditions. Stirring of the melt, simulating flow or convective conditions, facilitates nucleation and growth of crystals via mechanical transportation of matter, resulting in the higher J and G observed. Any modeling pertaining to magma dynamics in the conduit (e.g. ascent rate) and lava flow emplacement (e.g flow rate, pahoehoe- ‘a’a transition) should therefore take the effects of dynamic crystallization into account.

Development of an active alkaline trap to determine acidic gas ratios in volcanic plumes: sampling technique and analytical methods

Julian Wittmer[1], Nicole Bobrowski[1], Marcello Liotta[2], Sergio Calabrese[2], Giovanni Giuffrida[2], Ulrich Platt[1]

[1]*IUP Heidelberg, Germany*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy*

Determining volcanic gas composition helps to improve the understanding of the volcanic system, its effects on the atmosphere and the magmatic behaviour inside. In-situ measurements are the basis for the monitoring of volcanic gas emissions, being complemented by remote sensing techniques over the last years. Despite the established in-situ techniques to sample a diluted plume, an increase in accuracy and a reduction of detection limits are still necessary for most gases (e.g. CO2, SO2, H2S, HCl, HF, HBr, HI).

In this work, the Raschig-Tube, an established method for atmospheric research, was modified and utilised for application on volcanic plumes. The theoretical and experimental absorption properties of three different alkaline traps (Raschig-Tube, Drechsel bottle, filter pack) were characterised and the various sampling techniques were applied simultaneously in the field (Stromboli and Mount Etna) in order to compare the characteristics.

The comparison resulted in a high efficiency of the Raschig-Tube technique to trap acidic gases. Applying the Raschig-Tube (see Figure 1) allows higher sampling flow rates and the use of less sampling solution with respect to the Drechsel bottle. In this way higher concentrations of dissolved species within a shorter time are obtained.

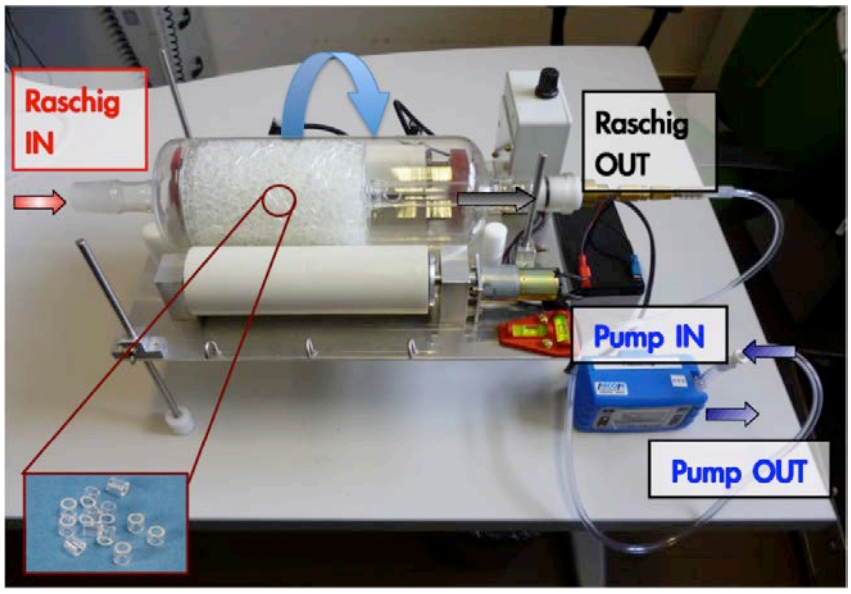

Figure 1. Operating mode of the Raschig-Tube. The small and coloured arrows indicate the direction of the gas flow and the blue curved arrow shows the rotation.

Additionally, the analytical procedure, including sample preparation, analysis by Titration, Ion Chromatography (IC) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS), was optimised to accurately quantify molar concentrations of dissolved compounds.

The progress in sampling and analysis led to a significant high quality data set that covers a wide range of elements. In particular, less abundant species were quantified more accurately. The results show slight deviations for various sampling techniques mainly caused by the different characteristics and analyte concentrations.

At Stromboli, iodine was detected for the first time and resulted in S/I ratios between 80,000 and 280,000. Moreover, CO2/SO2, S/Cl, S/F and S/Br ratios were obtained and are in rough agreement with previous studies [e.g. Burton et al., 2007; Allard et al., 2000; Aiuppa and Federico, 2004].

For Mount Etna samples from 2010 to 2012 were evaluated, taken at the rim of the North-East crater (NEC) and the Bocca Nuova crater (BN). Whereas NEC results show a relatively small range, higher variations can be seen for BN probably caused by different sampling conditions, the applied instrumentation and the state of activity. The obtained ratios are discussed and compared with those given in previous studies [e.g. La Spina et al., 2010; Aiuppa et al., 2005; Allard et al. 2005; Burton et al., 2003].

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Multidisciplinary monitoring of volcanic activity during the July-August 2011 lava fountain activities occurred on Etna Volcano

Luciano Zuccarello[1,2], Daniele Carbone[1], Mauro Coltelli[1], Danilo Contrafatto[1], Alfio A. Messina[3], Domenico Patanè[1], Michele Prestifilippo[1], Salvatore Rapisarda[1], Gilberto Saccorotti[4], Simona Scollo[1], Luciano Scuderi[1], Gaetano Spata[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*University College Dublin, School of Geological Sciences, Dublin, Ireland*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione Geomagnetismo, Aeronomia e Geofisica Ambientale, Roma, Italy*
[4]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Italy*

Volcanic eruptions are preceded by a wide range of observables (seismic activity, ground deformation, gas emission) which can be used for hazard mitigation. Continuous monitoring of seismic activity, such as long-period events and volcanic tremor, gives important information on the state of activity at a volcano. Nevertheless, volcanic tremor is among the most difficult geophysical signals to interpret. The lack of clear body-wave phase arrivals, and the rapid loss of signal coherence with the increasing station spacing, makes it impossible to retrieve source location by means of the hypocenter determination techniques, adopted in classical seismology. However, location of the tremor source is a critical aspect toward a better understanding of the evolution of the volcanic activity, because of its strict relationships with eruptive mechanisms and, more generally, with fluid flows through the volcano's feeding system. For this reason, with the main aim of improving our understanding of the volcanic activity at Etna Volcano, during July and August 2011, we temporally augmented the permanent monitoring system in the summit area with a small-aperture (ca. 100 - 150 m), broadband seismic antenna deployed on the South flanks of the volcano, at distances of about 1 km SW of the South East Crater.

Etna was very active in 2011-2012 producing twenty-five lava fountains. This activity was characterized by an almost constant eruptive behaviour with a gradual increase of volcanic tremor, strombolian activity and a paroxysmal phase that produced eruption columns ranging from few to ten kilometres of height and lasting from less than one hour to almost five hours. During the analysed period, corresponding to the paroxysmal phases of the July-August 2011 activity, we observed remarkable increments in the amplitude of tremor. Using the seismic signals from the nodes of the array, we performed correlation analysis after filtering the seismograms over narrow frequency bands. Significant wave-field coherence arises throughout the 0.5-1.5 Hz frequency band. For this frequency band, the propagation azimuth and apparent velocity of the incoming wavefronts were retrieved by inverting the inter-station delay times for the two cartesian components of the slowness vector, under a plane-wave approximation. Eventually, we obtained continuously 44-day-long time-series of propagation parameters for tremor waves recorded by the array. The most representative values of ray parameter are in the 0.6-1 s/km range, corresponding to apparent velocities between 1 and 1.6 km/s; these values are consistent with a wavefield composed by both surface and body-waves impinging at the array with shallow incidence angles. We observed significant changes in the distribution of the propagation parameters. The

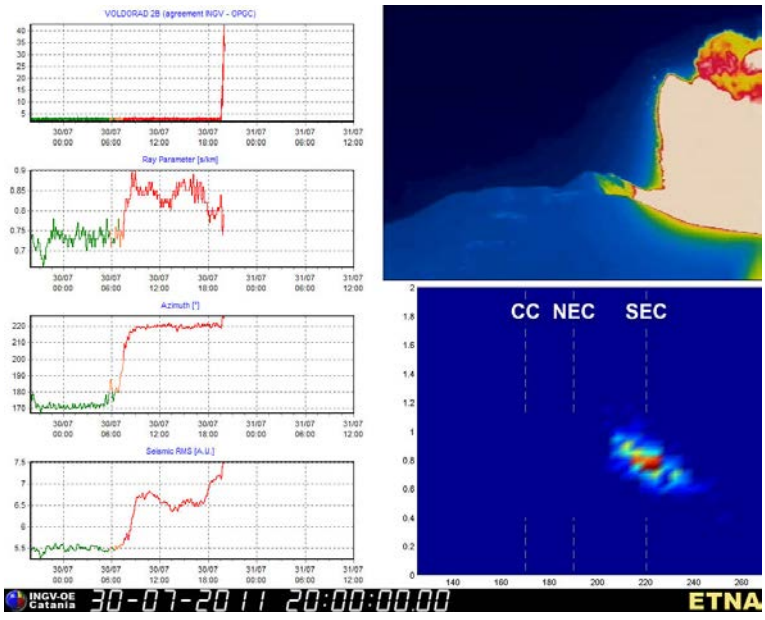

Figure 1. Correlation between seismic array analysis results and volcanological data during the paroxysmal phase occurred on 30th July, 2011.

propagation azimuth is clustered over the 160°-180° angular range in the quiescent periods but it turns anticlockwise 2/4 hours before the volcanic tremor amplitude increases, pointing to the South East Crater zone (around 200°-220). A further widening of the range of propagation azimuths occurs during the paroxysmal phase of each lava fountain episode, due to the contribution in the wavefield of the eruptive fracture located at the base of the South East Crater (around 230°).

Multi-channel techniques are able to track precisely the location of active magmatic fluids, several hours before the increase of the volcanic tremor. We also compared the seismic data with features of the eruptive activity and data from the radar doppler Voldorad installed at the top of Etna at about 3 km far from the South East Crater. The coupling between seismic array and volcanological data allows to better understand the eruptive dynamic in the shallow part of the plumbing system. We retain that the joint use of these techniques could be a valuable support to volcano monitoring activities.

Moment Tensor Inversion of Very Long Period (VLP) events recorded at Mt. Etna during the October 2005 – January 2006 time interval

Luciano Zuccarello[1,2], Ivan Lokmer[2], Christopher J. Bean[2], Gilberto Saccorotti[3], Domenico Patanè[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*
[2]*School of Geological Sciences, University College Dublin, Dublin, Ireland*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Italy*

Very Long Period (VLP) signals are commonly observed on active volcanoes, and are thought to reflect the elastic response of the conduit's walls to volumetric changes associated with mass (mostly gas) transport processes. Hence their detection and analysis represents a crucial step towards the quantification of mass budget during either quiescent or eruptive stages. The high interest in the correct determination of source parameters for VLP events in volcanic areas is mostly related to the fact that they can provide information not only on the geometry of the shallow part of the plumbing system, but also on the temporal changes of the source parameters. At Mt. Etna, more detailed investigations on low-frequency signals started systematically only since the installation of the broadband network (in late 2003), when sustained VLP activity was observed for the first time both during the quiescence periods and the summit eruptive phases. In this work we present results from the moment tensor inversion of VLP recordings obtained at Etna Volcano, Italy, during the October 2005 - January 2006 time interval, when an increase in the amplitude of the volcanic tremor was observed at Mt. Etna in the almost complete absence of eruptive activity. Through an automatic detection procedure, more than 10000 VLP events were recognized, and, using both semblance method and the particle motion direction, their source was located beneath the summit craters, at an average depth of 800-1000 m. For this position, we calculate the Green's functions at the stations of the seismic broad band permanent networks, using a three-dimensional discrete elastic lattice method. We then performed a Moment Tensor inversion of the VLP source using a frequency-domain, full-waveform inversion of the broad-band ground displacement recordings. Our results suggest a source mechanism with a prevalent volumetric component, with a maximum incremental volume change of about 100 - 300 m3. Moreover for a given source mechanism and source location, the scalar moment scales linearly with ground displacement at a given site, and we find a conversion factor between vertical-component ground displacement at the seismic broad band station (i.e. ECPN station) and volume change at the VLP source.

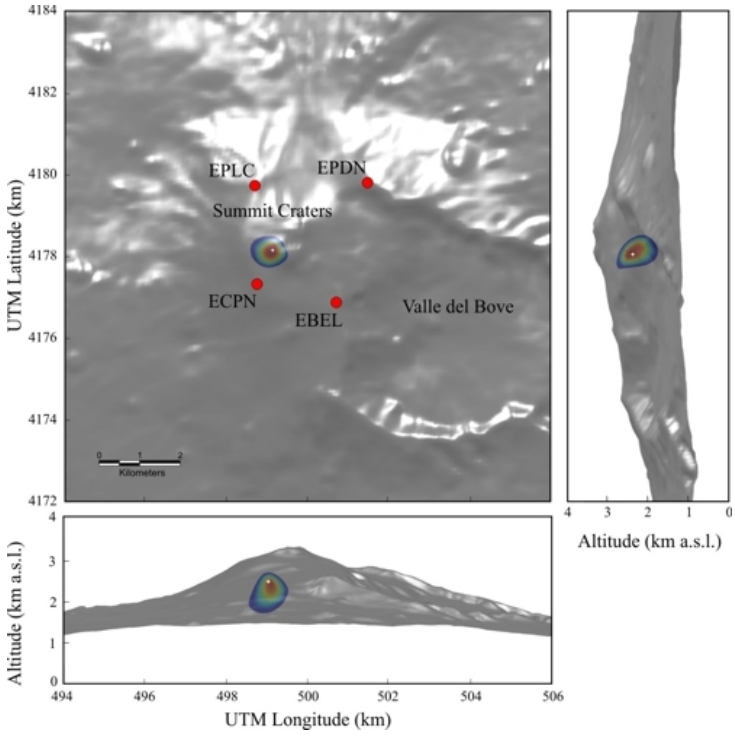

Figure 1. Maximum-Likelihood hypocenter locations in map view (top), longitude (bottom) and latitude (right) sections, of the VLP events. White stars mark the location obtained from the most energetic VLP event by using the semblance method.

Although further tests are needed to better elucidate stability and robustness of our inversions, this study represents the first attempt of quantitative analysis of VLP source at Etna, and opens the way to the establishment of automatic procedures aiming at the real-time evaluation of volumetric changes due to unstable mass flow throughout the shallow plumbing system.

Coordinamento editoriale e impaginazione
Centro Editoriale Nazionale | INGV

Progetto grafico e redazionale
Daniela Riposati | Laboratorio Grafica e Immagini | INGV

Via di Vigna Murata, 605
00143 Roma
Tel. +39 06518601 Fax +39 065041181

http://www.ingv.it

Istituto Nazionale di Geofisica e Vulcanologia