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In copertina | *Cover* Parossismo dell'Etna del 4 dicembre 2015 (Photo: Giuseppe Famiani)

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SESSION 1

Magmas and feeding systems

Convenors: Paola Donato and Marco Viccaro

Tracing the sediment recycling into the mantle: application of Molybdenum isotopes to ultrapotassic Italian rocks

Martina Casalini[1]*, Riccardo Avanzinelli[1], Tim Elliott[2], Simone Tommasini[1], Sandro Conticelli[1,3]

[1]Dipartimento di Scienze della Terra, Università degli Studi di Firenze, Italy
[2]School of Earth Sciences, University of Bristol, UK
[3]Istituto di Geoscienze e Georisorse, CNR, Firenze, Italy
*Presenting author

The study of non-traditional stable isotopes has provided new means to decipher the contribution and the nature of the recycled materials in subduction zones (i.e., fluids vs. melts). Molybdenum isotopes have been shown to fractionate in superficial environment entailing the formation of reservoirs with different isotopic compositions. Although the geochemical behaviour of Mo is still not completely understood, it has been suggested that Mo has substantially incompatible behaviour in the dominant mantle mineralogy but can be sometimes compatible in accessory phases (i.e., rutile and sulphide). The geochemical and isotopic budget of subduction-related magmas is strongly dependent on the nature and composition of the recycled material but also on the residual mineralogy during melting. In this light, the coupling between Mo and traditional trace elements in subduction-related magmas is able to highlight the occurrence of specific residual phases reflecting the composition of the recycled material. The peculiar geochemical and radiogenic isotopic signatures of the Italian potassic and ultrapotassic rocks of the Tuscan magmatic province and Mount Vesuvius require the involvement of sediment-dominated subduction component in their mantle source. These rocks represent an interesting case study for tackling the role of different subduction-related metasomatic agents using Mo.
The measurements of Mo contents and δ^{98}Mo values on rocks and sedimentary composites as proxy of the recycled material, highlight that the absolute Mo content, although different between the two areas, is depleted compared to other incompatible trace elements, whilst isotope composition is similar but still heavier than other subducted-related magmas. Such features are discussed considering i) original differences in the down-going sediments; ii) fractionation during sediment subduction/melting constrained by residual phases, and iii) elemental or isotope fractionation en route to the surface.

Unravelling plumbing system dynamics linked to explosive eruptions by geochemical and isotopic micro-analyses: the case study of Campanian Ignimbrite, Campi Flegrei, Italy

Sara Di Salvo[1*], Riccardo Avanzinelli[1], Roberto Isaia[2], Tim H. Druitt[3], Lorella Francalanci[1]

[1]Dipartimento di Scienze della Terra, Università degli Studi di Firenze, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy
[3]Université Clermont Auvergne-CNRS-IRD, OPGC Laboratoire Magmas et Volcans, Clermont-Ferrand, France
*Presenting author

Caldera-forming eruptions, related to large volumes of magma from shallow crustal reservoirs, are one of the most dangerous natural events on Earth. The Campanian Ignimbrite (CI) represents a typical example of such kind of eruption, and it is associated to a pyroclastic sequence of trachytic to phonolitic magma. In this study we have investigated CI proximal deposits, focusing on the possible presence of geochemical and Sr and Nd-isotope heterogeneities in the magma components involved in the CI plumbing system and we have evaluated the condition of geochemical and isotopic (dis)equilibrium between crystals and their host melts.

All units, with the notable exception of the last erupted one (UPFU), have low crystal content, evolved matrix glass compositions, negative Eu anomalies (0.2-0.6), strong micro-scale geochemical and isotope heterogeneities and phenocrysts mostly showing disequilibrium textures. On the other hand, the last erupted unit UPFU shows significant differences: higher phenocryst content, less evolved matrix glass compositions, positive Eu anomalies (1.0-1.4), less Sr- and Nd-radiogenic signatures and high-Or (83-87) sanidine with equilibrium textures. Glasses from the more evolved units represent liquids segregated within a geochemically and isotopically heterogeneous crystal-mush reservoir, after the arrival of the UPFU “mafic” melt, which represents a new magmatic component entering and un-locking the cumulate system. UPFU evolved by a combination of processes that includes partial melting of mush-derived crystals, mixing and fractional crystallization.

This micro-analytical geochemical and isotopic study adds further and important constraints to the evolution of the reservoir of large explosive eruptions such as the CI. Our data suggest that magmas can remain isolated and “locked” within a crystal mush, only to be thermally re-activated by a new batch of fresh magma, than segregated and finally erupted without time to re-equilibrate.

The effect of decompression and water content on the degassing pattern of trachytic magmas

Anush Kazarian[1]*, Francisco Cáceres[2], Bettina Scheu[2], Valeria Misiti[3], Alessandro Vona[1], Don B. Dingwell[2], Claudia Romano[1]

[1]Dipartimento di Scienze, Università degli Studi Roma Tre, Roma, Italy
[2]Earth & Environmental Sciences, Ludwig-Maximilians-Universität, Munich, Germany
[3]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Sismologia e Tettonofisica, Roma, Italy
*Presenting author

Rapid decompression of magma is an important trigger for magma fragmentation and explosive eruptions, acting primarily in two possible ways: drop of the confining pressure, with consequent acceleration of magma, or development of bubble overpressure. In this regard, it is important to improve the investigation on degassing processes in magmas, as a crucial key for understanding fragmentation mechanisms and eruption behavior of different magmas.
This study investigated the influence of the physical state of a trachytic magma (volatile content, bubble content and shape) and of the decompression style (rapid, one-step, multi-step, dP/dt) on the degassing process. We performed isothermal decompression experiments with a shock-tube apparatus at T= 750-850° C, in the liquid state. Hydrous homogeneous glasses (H_2O = 0.35 wt%, 0.5 wt%, 1.77 wt%) were decompressed from starting undersaturated conditions (P = 22-6 Mpa) to oversaturated pressure conditions and then to ambient pressure. Textural features of the degassed samples were related to the style of decompression (eg., decompression rates, annealing time) and to the initial water content (H_2O = 0.35 wt%, 0.5wt%, 1.77wt%). Compared to literature for different melt composition, the results showed good consistency. Further, we observed heterogeneous distributions of bubble populations leading to variable bubble number densities, with both likely associated to diffusive-degassing.
The results presented here stem from a successful feasibility study. Future thorough investigation of the different degassing styles of trachytes via vesiculation and water diffusivity as well as their influence on the rheology of magmas in the conduit will follow.

Rapid carbonate assimilation as eruption trigger: new insights from a Somma-Vesuvius (Italy) plinian eruption

Gianmarco Buono[1*], Benjamin R. Edwards[2], Sara Fanara[3], Chris Harris[4], Lucia Pappalardo[5], Paola Petrosino[1]

[1]Università di Napoli Federico II, Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse, Napoli, Italy
[2]Dickinson College, Department of Earth Sciences, Carlisle, USA
[3]University of Göttingen, Institute of Mineralogy, Göttingen, Germany
[4]University of Cape Town, Department of Geological Sciences, Cape Town, South Africa
[5]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy
*Presenting author

The majority of Italian volcanoes lie on carbonate basement. Several petrological evidence of magma-limestone interaction has been recognized for these volcanic systems. Recently, analytical and experimental investigations on carbonate assimilation have been carried out on worldwide active volcanoes (e.g. Colli Albani, Merapi, Popocatepetl, Somma-Vesuvius). These studies suggest that magma-limestone exchange can be very rapid and can promote large amounts of crustal CO_2 release with potential significant consequences on eruption intensity and style. Therefore it is critical to estimate the mechanisms and timescale of this process. In this study we have explored the role played by limestone contamination on eruptive dynamics of Pomici di Base plinian eruption, the oldest (22 ka) and largest (volume ≥ 4.4 km^3) explosive event of the Somma-Vesuvius. During this eruption the column reached an height of 16-17 km (MDR = 2-2.5x107 kg/s) and remained stable during the whole plinian phase despite a marked compositional variation from trachytic to latitic-shoshonitic magmas (~25% and ~75% of volume respectively). Here we have combined 3D textural (X-ray microtomography) and geochemical (major-volatile elements and stable-radiogenic isotopes) investigations with thermodynamic modeling (alpha-MELTS and EC-AFC simulations, heat transfer and rocks dissolution rate calculations).
Our results show that, after the withdrawal of the upper trachytic liquid, the remnant hotter (1000-1050° C) mafic magma was affected by fast (minutes to days) limestone ingestion during its ascent towards the surface. The resultant rapid CO_2 liberation pulses contributed to amplify the eruption intensity despite the magma's low viscosity (~2 Pa/s). We conclude that shallow carbonate interaction can strongly influence eruption explosivity on a short timescale with potential implications on the behavior of geochemical signals detected by monitoring systems.

Crystal-melt-bubble diffusion of volatiles as a clue for fixing magma degassing timescales

Marisa Giuffrida[1*], Francesco Zuccarello[1], Marco Viccaro[1,2]

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

The temporal quantification of magma ascent and degassing processes is a key for the evaluation of hazard associated to violent explosive eruptions at active volcanoes. Direct and reliable measurements of such short-lived processes can be derived through diffusion chronometry-based investigations of volatile components that rapidly diffuse in volcanic minerals and glasses, and allow therefore to track the late stage ascent ad degassing paths of saturated magmas culminating in explosive eruptions.
Here, we show how the concentration and diffusion profiles of H_2O, CO_2 and S measured in crystal-hosted melt tubes may be successful employed to recognize and quantify multiple episodes of melt-bubble diffusion exchange of such volatiles in a shallow magmatic system. In turn, the preservation of Li concentration gradients in plagioclase may imply significant diffusive disequilibrium during the final stage of crystal growth as a consequence of the rapid depletion of Li from the melt through sin-eruptive degassing. Modeling the diffusion of Li between plagioclase and its hosting melt allows, therefore, determination of the timescales of decompression-driven magma degassing just before or even during an explosive eruption.
The application of such diffusional methods to some exceptionally violent eruptions that were generated at Mt. Etna from the New South East Crater and Voragine between 2011 and 2016 has led us to recover unusually short timescales (1-2 minutes) of re-activation of the magmatic system likely triggered by gas flushing. Our current knowledge on depths of storage levels beneath the volcano, based on seismic signals, finally yields to the final magma ascent rate for selected eruptions at Etna, which compares quite well with rates of syn-eruptive magma ascent retrieved for closed-system volcanoes erupting on Earth.

Rejuvenation mechanisms of a plumbing system: insights from the 2017 activity at Etna volcano

Francesco Zuccarello[1]*, Marisa Giuffrida[1], Stefano Gresta[1], Mimmo Palano[2], Mariabenedetta Scandura[1], Marco Viccaro[1,2]

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

After almost 8 months of quiescence, a new sequence of low-to-mild intensity eruptions characterized the activity of Etna volcano between January and April 2017. The activity started at a vent located between the old and the new cone of the South East Crater, and was characterized by weak-to-moderate Strombolian eruptions accompanied by lava flows. The weak volcanic events of 2017 constitute a breakpoint in the post-2011 eruptive behavior of Etna, which had shown the most explosive eruptions of the last two decades.
However, such activity revealed complex dynamics of magma ascent, which had required a multidisciplinary approach to be defined combining bulk rock compositions, crystal chemical zoning, diffusion chronometry and ground deformation. Bulk rock major and trace elements suggest that the 2017 magmas followed a distinct differentiation path than that experienced by other magmas erupted at Etna in recent years.
Analyses of olivine core compositions and zoning patterns, coupled with diffusion chronometry on olivine zoning, allowed us to obtain spatial and temporal reconstruction of magma dynamics into the plumbing system, which is characterized by a presence of multiple magmatic environments activated before and during the 2017 eruptive events. Results well correlate with the ground deformation stages detected through geodetic data inversion.
Combination of all petrologic and geodetic observations supports the idea that the violent eruptions occurred at Voragine Crater on May 2016 enhanced the ascent of fresh magma from deep storage zones that fed the eruptive episodes of 2017. We propose a mechanism of self-feeding rejuvenation of the volcano plumbing system during 2017 as a consequence of the paroxysmal events occurred on May 2016, where fresh recharging magmas ascending from depth progressively pushed away the residual ones stored at shallow crustal levels.

Clinopyroxene growth rate: experimental investigation at crustal-mantle boundary level in an alkaline basalt from the Campi Flegrei Volcanic District (South Italy)

Barbara Bonechi*, Cristina Perinelli, Mario Gaeta, Vincenzo Stagno

Dipartimento di Scienze della Terra, Università La Sapienza, Roma, Italy
*Presenting author

The kinetics of crystal nucleation and growth are fundamental for the interpretation of thermal history of a magma during its ascent to the surface, and to constrain timescales of magmatic processes. In basaltic systems clinopyroxene (Cpx) is a common phenocryst, and due to its wide crystallization range, it contains the most complete record of evolutionary history of a magma. Nevertheless, to date, experimental studies addressed to obtain measurements of Cpx growth rate are few and limited to low pressure (≤ 0.5 GPa).
In this experimental work, we investigated the effects of temperature, water content and time on Cpx growth rate in an alkaline basalt (APR16 sample) from Procida island, representative of the least-evolved rocks of the whole Campi Flegrei Volcanic District (Italy). The starting material is an anhydrous glass prepared by melting the APR16 natural powder in a gas-mixing furnace at 1400 °C and atmospheric pressure. Experiments were performed at isobaric pressure (0.8 GPa) by using the piston cylinder apparatus at the HP-HT Laboratory of the Earth Sciences Department, Sapienza, University of Rome. We performed a total of 24 experiments divided into three series. Experiments of series 1 were carried out at anhydrous conditions at 1250°C and 1200° C and dwell time of 0.25, 3, 6 and 9 hours. Experiments of series 2 and 3, instead, were carried out at hydrous conditions (2 and 4 wt% H_2O added to the starting material, respectively), 1220° C and 1170° C (series 2) and 1080° C and 1030° C (series 3), and the same dwell time of series 1.
Results show that crystal sizes increase increasing the duration of the experiments with values between 5 and 20 µm. Moreover, we noted a strong growth rate dependence on time in all the runs, while temperature and water content play a minor role. Obtained Cpx growth rate values range from 10-7 to 10-8 cm/s, varying of an order of magnitude increasing the duration of the experiments.

A LA-ICP-MS study of carbonatites from Fuerteventura, Canary Islands

Gabriele Carnevale[1*], Alessandra Correale[1], Antonio Paonita[2], Silvio G. Rotolo[1], Xabier Arroyo Rey[3]

[1]Dipartimento di Scienze della Terra e del Mare, Università degli Studi di Palermo, Palermo, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Palermo Italy
[3]CAI Técnicas Geològicas, Universidad Complutense de Madrid, Madrid, Spain
*Presenting author

Carbonatites complexes are rare in oceanic environments and in the Atlantic Ocean they can be only found only at Cape Verde islands and Fuerteventura. Fuerteventura is the second largest island in the Canary Archipelago and is located on a transitional, continental to oceanic, crust. It consists essentially of Mesozoic sediments, submarine volcanic rocks, subaerial basaltic and trachytic series, ultramafic, mafic to felsic intrusives (clinopyroxenites, ijolites, nepheline-gabbros, nepheline-sienites) and carbonatitic dike swarms (age 25 Ma).
Carbonatite dike (Ca-carbonatites) mineralogy consists of calcite, aegirine-augite, albite, K-feldspar, biotite, apatite, Fe-Ti oxides and accessory minerals, such as zircon, barite, monazite and pyrochlore. The degree of alteration of carbonatites (evaluated by DTA and XRD) is generally low, with the occurrence of illite-montmorillonite mixed layers, vermiculite and chlorite. Whole rock samples (XRF) are high in CaO (>50%) and SrO (>2%) and very low in MgO.

Magmatic processes at La Fossa volcano (Vulcano Island, Italy): evidences from temperature gradient experiments

Simone Costa S.[1*], Matteo Masotta[2], Anna Gioncada[2], Marco Pistolesi[2]

[1]Dipartimento di Scienze della Terra, Università degli Studi di Firenze, Firenze, Italy
[2]Dipartimento di Scienze della Terra, Università di Pisa, Pisa, Italy
*Presenting author

The eruptive sequence of Palizzi is a complex volcanic succession emplaced at La Fossa volcano (Vulcano, Aeolian Islands) during the 13th century. The erupted products range in composition from latite to rhyolite, with a wide range of K_2O content in the trachytic field. Pumice clasts collected from the main trachytic sub-Plinian fallout exhibit the highest K_2O concentration among the eruptive products of Vulcano Island, remarkably higher than any trachytic magmas with similar silica content erupted at La Fossa. In order to investigate the magmatic processes that produced this evolved composition, we have experimentally simulated crystallization and differentiation in presence of a temperature gradient, using a latitic starting composition (enclave of the AD 1739 Pietre Cotte lava flow).
Experiments were performed at pressure of 150 MPa and temperature of 1050-950° C (hot and cold zone, respectively), at both hydrous (H_2O=2 wt.%) and anhydrous conditions, to reproduce a compositionally and thermally zoned shallow magma reservoir. Mineral phases include clinopyroxene (first liquidus phase), oxides, alkali feldspar (more abundant at anhydrous condition) and biotite (at hydrous condition only). At anhydrous conditions, glass composition along the crystallization gradient enriches in alkali (Na_2O+K_2O ranging from 10.7 to 11.7 wt.%) with a nearly constant SiO_2 (59±0.5 wt.%), heading towards the matrix glass compositions of the trachytic natural pumice. In contrast, at hydrous conditions, the SiO_2 content increases from 58.5 to 62.2 wt.%, with an initial increase in alkali composition (Na_2O+K_2O ranging from 10.2 to 10.9wt.%) before stabilizing at a constant value of ~11.2 wt.%, approaching the trachytic differentiation trend shown by La Fossa products.
Experimental results suggest that the H_2O content in the melt exerts a primary control on phase stability in the pressure range of La Fossa magmas, thus determining the differentiation trends of the erupted magmas.

Understanding the origin of magmatic necks: insights from Mt. Etna volcano (Italy) and analogue models

Margherita Fittipaldi[1*], Stefano Urbani[1], Marco Neri[2], Daniele Trippanera[1,3], Valerio Acocella[1]

[1]Dipartimento di Scienze, Università Roma Tre, Roma, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy
[3]King Abdullah University of Science and Technology, Thuwal, Saudi Arabia
*Presenting author

Magmatic necks are commonly found in volcanic areas and they often exhibit a homogeneous structure with cylindrical shape and diameter of up to several hundreds of meters. Their massive and uniform structure poses a space problem for their emplacement in the brittle crust. Here we use field data and analogue models to investigate how necks may emplace at shallow levels. Field analysis focuses on characterizing the geometric, structural and magmatic features of two necks outcropping in the eroded portions of Mt. Etna, Italy. These are homogeneous and massive intrusive bodies, related to a single episode of emplacement at 400-600 m below the paleo-surface. We further investigated their possible emplacement mechanism through analogue models, injecting vegetable oil within a a) flat sand-pack and b) sand-cone. Dikes form with both configurations, erupting to the surface through vents. However, dikes injected within the cone are characterized by a larger thickening at shallow levels, in correspondence with the vent, where a neck-like structure forms. This suggests that the gravitational load imposed by a volcanic edifice provides the most suitable conditions for the development of magmatic necks as the downslope shear stresses enhance the deformation of the cone slope during shallow dike emplacement promoting shallow dilation and thickening of the dike. Therefore, topography should be a further factor enhancing the development of necks, in addition to those mechanisms previously proposed.
Our results are consistent with natural examples of feeder dikes thickening towards the surface and dikes transitioning to necks, supporting the reliability of the proposed conceptual model.

Investigating heterogeneous magma systems by detailed characterisation of the juvenile products: example from the Upper Pumice eruption of Nisyros Volcano (Greece)

Filippo Mastroianni[1,2*], Eleonora Braschi[3], Sara Di Salvo[1], Georgios E. Vougioukalakis[4], Lorella Francalanci[1]

[1]Dipartimento di Scienze della Terra, Università degli Studi di Firenze, Firenze, Italy
[2]Dipartimento di Scienze della Terra, Università di Pisa, Pisa, Italy
[3]CNR - Istituto di Geoscienze e Georisorse, Italy
[4]IGME - Institute of Geology and Mineral Exploration, Acharnae, Athens, Greece
*Presenting author

To better understand the behaviour of active volcanoes and to assess the hazard related to their eruptive activity, is fundamental to reconstruct the history of these systems and to have a deep knowledge of magmatic processes leading to eruptions with different styles.
In this view, we investigated the pyroclastic succession produced by the last caldera-forming sub-plinian eruption at Nisyros Volcano (Dodecanese, Greece), called Upper Pumice (UP). The UP succession is constituted of deposits generated by processes of fallout, interlayered with and then substituted by diluted pyroclastic density currents (PDCs) toward the top and closed by a lag-breccia unit overlaid by a grey ash flow level. The juvenile is mainly represented by white-yellow pumices of moderate crystallinity and rhyo-dacitic composition. To a lesser extent (≈4%), the fallout includes dense, crystalline juvenile lapilli clasts with rounded shape, often mingled with pumices having andesite to dacite composition. They show a large variability in textures, from peculiar dictytaxitic to more vesiculated, where crystals appear fragmentated inside the ground mass. In the lag-breccia unit, the juvenile andesitic magma is represented by dense, grey, crystalline bombs, with crenulate surfaces, showing dictytaxitic texture in almost every sample. While pumices from all deposit are chemically similar for major and trace elements and for isotopic composition (Sr-Nd isotope values clustered around 0.70456 and 0.51226), dense crystal-rich clasts show evident compositional variation roughly correlated with their textural feature. In these clasts, $^{87}Sr/^{86}Sr$ ranging between 0.70420-0.70489, with the lowest values found in the lag-breccia unit.
Such chemical, isotopic and petrographic differences obtained during a single eruption point to the presence of two or more, non-cogenetic, variably evolved magmas interacting in the reservoir leading to a complex pre- and eruptive dynamic.

X-ray microtomographic investigation to explore magma mixing as eruption trigger: the 4.1 B.P. Agnano Monte Spina (Campi Flegrei, Italy) plinian eruption case study

Carlo Pelullo[1,2*], Ilenia Arienzo[1], Massimo D'Antonio[2], Lucia Pappalardo[2], Paola Petrosino[1]

[1]Università di Napoli Federico II, Dip. di Scienze della Terra, dell'Ambiente e delle Risorse, Napoli, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy
*Presenting author

Magma mixing is considered one of the main processes in triggering highly explosive volcanic eruptions. In fact, the input of fresh, higher-temperature magma intruding into a magma chamber may drive volatile transfer from one magma to another and volatile exsolution, increasing the volumetric stress in the chamber and destabilizing the magmatic system. In this way, the volume increase may accelerate magma ascent and the vesiculation upon decompression reaches, consequently, a point of no return and an eruption becomes unavoidable. The X-ray computed microtomography (microCT) technique is a powerful tool to provide three-dimensional information on rock samples and to evaluate the textural disequilibrium due to mixing processes.
Such studies can play a fundamental role in contributing to volcanic hazard assessment, particularly in densely inhabited areas. The 4.1 ka B.P. Agnano–Monte Spina (AMS) eruption, considered as reference event for a future large-size plinian explosive eruption at Campi Flegrei (South Italy), is mentioned in previous studies as result of a magma mixing process. Petrological data, trace elements and isotopic composition suggest that at least two magmas have interacted during the eruption. In order to infer this hypothesis, we are analyzing the AMS products via micro-CT images. X-ray microtomographic analysis provide quantitative 3D textural features, involving vesicle and crystal distributions, filament morphology and further textural characteristics otherwise obscured in conventional 2D observations and analyses.
Vesicles in volcanic rocks are frozen records of degassing processes in magmas. For this reason, their sizes, spatial arrangements, numbers and shapes can be linked to physical processes that drive magma ascent and eruption. These studies will shed new light on the complex interplay of processes determining bubble formation during magma mixing, ascent and eruption.

A petrological study of some mafic and felsic tephra at Ustica Island, southern Tyrrhenian Sea

Pierangelo Romano P.[1,3], Chiara Tubbiolo[1*], Patrizia Landi[2], Silvio G. Rotolo[1,3], Sandro de Vita[4]

[1]Università degli Studi di Palermo, Dipartimento di Scienze della Terra e del Mare, Palermo, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Pisa, Italy
[3]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Palermo, Italy
[4]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy
*Presenting author

Ustica Island is the subaerial portion of a much larger edifice whose base lies 2000 m below the sea level. The oldest documented eruptive activity dates 750 ka (hyaloclastite breccias and pillows lavas), the youngest has an age around 120-130 ka (the Falconiera tuff cone). Among the explosive eruptions, mafic pyroclastic surge deposits are recurrent throughout the volcanological history of Ustica: (i) the widespread M. Costa del Fallo Unit [De Vita et al., 1998], in the central part of the island and (ii) the Falconiera tuff-cone in the northwest sector of Ustica. The only felsic (trachytic) tephra is the (iii) Grotta del Lapillo pumice fallout, erupted during the most energetic event eruption of the island (likely sub-plinian).
We present the results of a petrological study of the above-mentioned deposits, combining analysis of whole rocks (major and trace elements), minerals, groundmass glasses and melt inclusions (MIs). Mafic products (i.e. Costa del Fallo, Falconiera surge deposits and Monte Guardia dei Turchi strombolian spatter-cone) have similar composition (olivine Fo_{88-72}; plagioclase An_{65-72}) while mineral compositions in trachytic tephra show a large compositional range; olivines are in the range Fo_{9-74}, and feldspar varies between Or_{0-45}, Ab_{12-82}, An_{0-88}. MIs composition range from 46 to 63 wt.% SiO_2 and Na_2O+K_2O = 4-10 wt.%. H_2O concentration in MIs of mafic products is in the range 0.5 and 1 wt%, while in trachytic tephra varies from 1 to 3.2 wt%. CO_2 concentration is generally below the detection limit (50 ppm) of the FT-IR spectrometer, only in the mafic products a CO_2 concentration up to 600 ppm has been determined.
Our results allow adding further constraints to the pre-eruptive storage condition of the magmas that fed the most energetic eruptions at Ustica Island and obtaining new insights in understanding the plumbing system of Ustica volcanic complex.

Estimating the intruded vs. erupted magma budget at Mt. Etna during the March 2015 - May 2016 period

Gaia Sacco[1*], Tommaso Caltabiano[2], Giuseppe Salerno[2], Marco Viccaro[1,2]

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

In this study, we present the daily SO_2 flux observed at Mt. Etna throughout the period March 2015 -May 2016. Over the investigated period, Mt. Etna volcano was characterized by three eruptive events at the New South East Crater and Voragine (May 2015 - NSEC, December 2015 and May 2016 -VOR and NSEC), which ranged from weak Strombolian to extremely vigorous lava fountaining [Cannata et al., 2018; Corsaro et al., 2017]. SO_2 fluxes showed rather low values, generally below 5000 tons/day (t/d), for most of the period during March 2015 -May 2016. Steady increase with values up to 9500 t/d marked especially the onset of eruptive activity. The volume of degassed magma is 1.4 x 10^5 m^3 and 2.6 x 105 m^3 at 1 March 2015 and 31 May 2016, respectively. The total average volumes erupted during the three main eruptive episodes are the following: (1) May 2015: 3.9 x 10^6 m^3; (2) December 2015: 9.7 x 10^6 m^3; and (3) May 2016: 5.6 -8.8 x 10^6 m^3 [data from Corsaro et al., 2017; Branca, personal communication]. This allows estimating a total average erupted volume of magma of about 2.0 x 10^7 m^3 over the considered period. Assuming the total volume of degassed magma on 31 May 2016 (1.2 x 10^8 m^3), the balance between the degassed and erupted magma yields a volumetric ratio of about 6:1, which means a volume of intruded and not erupted magma of about 1.0 x 10^8 m^3. This ratio implies two scenarios, in which intruded magma can be either stored at depth within the crust, undergoing continuous degassing, or its potential upward remobilization only through recharge from depth by gas-rich magma injections or gas flushing processes.

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H_2O-CO_2 solubility in a trachytic melt from the Pomici di Base Plinian eruption of Somma-Vesuvius

Monica Spagnoli[1]*, Max Schanofski[2], Gianluca Sottili[1], Sara Fanara[2]

[1]Dipartimento di Scienze della Terra, Università la Sapienza, Roma, Italy
[2]Institute of Mineralogy, Georg-August University, Gottingen, Germany
*Presenting author

H_2O-CO_2 solubility experiments on a trachytic melt from the Pomici di Base Plinian eruption of Somma-Vesuvius were conducted in an Internally Heated Pressure Vessel (IHPV) at the Mineralogy Department of University of Göttingen (Germany). Experiments with five capsules with variable H_2O-CO_2 contents (XH_2O = 0, 0.25, 0.50, 0.75, 1) were performed in the same run. The experiments were carried out at 1,250° C and at pressures of 50, 100, 200 and 300 MPa for run duration of approx. 24h at intrinsic oxygen fugacity (fO_2 = NNO+4). The chemical composition of the starting glass was analysed with X-ray Fluorescence. The H_2O and CO_2 content of the obtained glasses were quantified using the Fourier Transform Infrared Spectroscopy (FTIR) in association with the thermogravimetry and the carbon-sulfur analyser. FTIR spectra show that molecular CO_2 is present in the trachytic glass besides carbonate. Until now, molecular CO_2 was commonly found in rhyolitic and dacitic melts but not in other trachytes (e.g. in the Campanian Ignimbrite trachyte, Campi Flegrei).
First results show that the solubility in the trachytic melt from Pomici di Base reaches the 5.50 ± 0.07 wt.% for H_2O and the 1,100 ± 200 ppm for CO_2 at 200 MPa, respectively. The new obtained H_2O-CO_2 solubility data will be interpreted in light of available theoretical models and experimental data on trachytic melts from previous studies.

What Drives the Lateral Versus Vertical Propagation of Dikes? Insights from Analogue Models

Stefano Urbani[1]*, Valerio Acocella[1], Eleonora Rivalta[2]

[1]Dipartimento di Scienze, Università Roma Tre, Roma, Italy
[2]Deutsches GeoForschungsZentrum GFZ, Potsdam, Germany
*Presenting author

Volcanic eruptions are usually fed by dikes. Understanding how crustal inhomogeneities and topographic loads control the direction (lateral/vertical) and extent (propagation/arrest) of dikes is crucial to forecast the opening of a vent. Many factors, including buoyancy, crustal layering, and topography, may control the vertical or lateral propagation of a dike.
To define a hierarchy between these factors, we have conducted analogue models, injecting water (magma analogue) within gelatin (crust analogue). We investigate the effect of crustal layering (both rigidity and density layering), topography, magma inflow rate, and the density ratio between host rock and magma. Based on the experimental observations and scaling considerations, we suggest that rigidity layering (a stiffer layer overlying a weaker one) and topographic gradient favor predominantly lateral dike propagation; inflow rate, density layering, and density ratio play a subordinate role. Conversely, a softer layer overlying a stiffer one favors vertical propagation.
Our results highlight the higher efficiency of a stiff layer in driving lateral dike propagation and/or inhibiting vertical propagation with respect to the Level of Neutral Buoyancy proposed by previous studies.

SESSION 2

Eruptive dynamics

Convenors: Paola Del Carlo and Roberto Sulpizio

Facies analysis of the 79 AD Vesuvius deposits observed during the recent excavations at Pompeii

Andrea Montanaro*, Annamaria Perrotta, Claudio Scarpati

Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse, Università Federico II, Napoli, Italy
*Presenting author

The most famous eruption of Mount Vesuvius took place in the year 79 A.D., when the volcano buried the ancient Roman city of Pompeii under a thick layer of pyroclastic materials (almost five metres) killing thousands of people. The city was rediscovered only in 1748 and from that date it was excavated but most of the volcanic material was removed without any geological descriptions. In the last years, the Great Pompeii Project is developing a special program of conservation, maintenance, and restoration. In this regard, excavation in Regio V is in progress with the aim of reducing the hydrogeological risk thanks to a re-profiling of excavation fronts with gentle slopes. During these new excavations, several ephemeral outcrops have been studied and great attention has been paid to the presence of lateral facies variations. The 79 AD stratigraphy in a formed by a 3 m thick basal fallout deposit and 2 m of stratified ashy sequence emplaced mainly by pyroclastic density currents. The basal lapilli fall deposit shows a remarkable thickness variation ranging from 2.7 m to 4.5 m.
Local overthickening is caused by sloping roofs which 'drained' a huge amount of fall pumice thus producing anomalous deposit thicknesses. Important lateral variations are observed in the upper part of the sequence. Single units show strong thickness variations from few cm to more than one meter. Basal contacts are sharp and locally erosive. Layers range from massive to thinly stratified and are mainly composed of fine ash. Pumice lapilli are dispersed in the lower part and decrease upwards where accretionary lapilli are abundant. The thickest unit has a valley ponding aspect and is locally confined. Thin, massive ash layers can be traced laterally into thick, poorly sorted, ash and lapilli layers, with well-developed sedimentary structures.
Lateral facies distribution of pyroclastic deposits within Pompeii are influenced by urban structures.

A new volume calculation of the Campanian Ignimbrite, Campi Flegrei, Italy

Aurora Silleni[1]*, Guido Giordano[1], Roberto Isaia[2], Michael Ort[3]

[1]Dipartimento di Scienze, Università di Roma Tre, Roma, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy
[3]Northern Arizona University, Flagstaff, USA
*Presenting author

The main Campanian Ignimbrite (CI), 39 ky, is interpreted as emplaced by a PDC that travelled more than 80 km and surmounted ridges more than 1000 m high [Fisher et al., 1993]. The calculation of DRE volume ranges from 23 to 300 km^3 [Scarpati et al., 2014]. This work deals with the calculation of the volume of the ignimbrite deposit, so far, the least constrained by field data. This is based on the development of an isopach map, from literature data and field work, in proximal medial and distal areas. Isopach lines were traced on a topographic slope map derived from a Digital Elevation Model, which show that the CI is dominantly valley ponded, with top surface never exceeding 20° and most commonly being ove new data and consideration, the total bulk volume of the ignimbrite is certainly greater than 100 km^3. Through the analysis of the thickness variation in relation to the topography, this study aims to understand the transport system of CI, proposed as a dilute current, but so far not fully explained [Fisher et al., 1993]. Moreover, it is fundamental to investigate the dynamics of extremely large volume pyroclastic flows, that they have not occurred in historic times, and there are few studies of them [Wilson, 2001; Wilson and Hildreth, 1997, 2003; Cas et al., 2011].

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Rheological behaviour of porous magmas

Stefania Sicola[1]*, Alessandro Vona[1], Claudia Romano[1], Amy G. Ryan[2], J. Kelly Russell[2]

[1]Università Roma Tre, Dipartimento di Scienze, Roma, Italy
[2]Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, Canada
*Presenting author

The presence of pores strongly controls the rheological behaviour of magma and thus influences all volcanic processes (pre- syn- and post-eruptive). Nevertheless, the effects of porosity on the rheology of magma are not well characterized, and a general parameterization is not available yet. Here we present a new set of experiments designed to investigate the rheology of pore-bearing melts at high temperature (750-800° C), low strain rates (10-6-10-7 s^{-1}) and variable porosity (10- 70% vol.). Experiments were performed at 1 atm using TMA on 5 x 5 mm cores of natural rhyolitic obsidian from Krafla, Iceland (vesicle and crystal-free) initially containing 0.11 wt% dissolved H_2O. The experimental procedure involves two main steps: 1) synthesis of bubble-bearing melts by heating and expansion due to foaming; for this stage, cores are heated above Tg (900-1050° C) and held degassing for set amounts of time (10–24 h); 2) cooling to variable target T (750-800° C) and deformation of the foamed samples upon a constant load (150 g). Two different experimental strategies are employed: 1) Single-stage: samples are deformed directly after foaming (without quenching); 2) Double-stage: pore-bearing melts are quenched after foaming, re-heated and deformed. In both cases, the variation in length (displacement) and volume (porosity) is continuously recorded and used to calculate the viscosity of the foamed cores using Gent's equations.
Results show lower effect of bubbles on the bulk viscosity of single-stage experiments than double-stage. This different behavior is related to the nature of the pores and the different microstructures affecting the experimental materials. The proposed viscosity models describe the rheological behavior of porous melts and can be applied to different pore framework (open-cell vs. closed-cell systems).

Volume-time distribution of lava flows and domes of the last 10 kyrs in Ischia Island (Italy)

Paolo Primerano[1]*, Guido Giordano[1], Sandro de Vita[2]

[1]Dipartimento di Scienze, Università degli Studi Roma Tre, Roma, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy
*Presenting author

The volcanic activity of Ischia can be subdivided in several periods. A significant change in average eruption rate and in geochemical composition of magmas occurred in the last 10ky after a 8kyr period of quiescence.
For this reason, last 10ky can be considered as a distinct period of activity respect to the preceding eruptive history of Ischia and is therefore chosen as a reference period for our analysis. The total number of eruptions occurred in the last 10ky is 49, with 36 eruptions in the last 3ky. The geochronological data for our analysis have been collected from available literature.
For lava domes and coulees the volumes have been calculated by masking a DEM with the lava extent identified by de Vita et al., [2010] and calculating the volume values above a set of reference plains. The products of the effusive activity are characterized by reduced erosional processes because of their recent emplacement and hard lithology. Because the intracalderic activity consist mainly in a monogenetic volcanic field, the products of the effusive eruptions are not, in general, overlapped. For these reasons we think that the uncertainty due to the resolution of the DEM and the unknown shape of the paleotopography onto which the lavas emplaced don't represent a significant uncertainty in the analysis. Volumes of the explosive eruptions have been estimated through a comparative analysis based on the dispersal area of Cretaio Tephra, which represents the highest magnitude event in the reference period. We evaluate that volumes involved in explosive eruptions are of similar order of magnitude of the effusive eruptions, in the range of $10^{-4}/10^{-1}km^3$.
From the diagrams it can be noticed that the current period of quiescence is comparable with the periods of quiescence occurred within the last 10ky. For this reason, while Ischia is at present quiescent, it is well within the activity framework that characterized the last 10ky.

Thermal regime of eruption column collapses and generation of hot pyroclastic flows

Matteo Trolese[1]*, Matteo Cerminara[2], Tomaso Esposti Ongaro[2], Guido Giordano[1]

[1]Dipartimento di Scienze, Università Roma Tre, Roma, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Pisa, Italy
*Presenting author

The temperature of pyroclastic density currents (PDCs) is one of the main hazards for communities and infrastructures surrounding volcanoes.
Our current understanding of thermal transport in PDCs is, though, still very limited. PDC deposits are known to vary from extensively welded to totally unwelded with emplacement temperatures close to ambient. The reasons for such great diversity are debated in terms of eruptive vs transport and emplacement processes. Here we present three-dimensional numerical simulations to understand the controls of different column collapse regimes on PDCs.
We find that the initial temperature of PDCs is linearly correlated with the amount of mass involved into the collapsing phase, and it can be decreased by up to 45% of the starting magmatic temperature in the case of incipient column collapse. This trend is observed independently of the simulated mass discharge rates. Our results suggest that an important imprint to the thermal character of PDCs is provided by the percentage of column collapse.

Experimental petrology data on pantelleritic melts/glasses

Paola Stabile[1]*, Ernestina Appiah[1], Harald Behrens[2], Gabriele Giuli[1], Eleonora Paris[1], Michael R. Carroll[1]

[1]School of Science and Technology, Geology Division, University of Camerino, Camerino, Italy
[2]Institut fur Mineralogie, Leibniz Universitat Hannover, Hannover, Germany
*Presenting author

Peralkaline melts occur in numerous tectonic settings, from oceanic islands (Ascension Islands) to continental rift zones (Pantelleria Island, Kenyan and Ethiopian Rift Valleys) and their eruptions can vary from lava flows to plinian or sub-plinian explosive styles. Experimental studies were conducted on pantelleritic compositions of the Kenya Rift Valley to constraint the magma storage conditions and volatile contents during magma eruptions. The alkali/Al ratio >1, higher total Fe and dissolved Cl and F contents, distinguish pantellerites from metaluminous magmas with similar Si content, resulting in large differences of their eruptive products and dynamics. Despite the volcanological interest, there is little literature on peralkaline melts and pantellerites. For this reason we focused on these melt compositions to investigate how oxygen fugacity and alkali content (as molar [Na/(Na+K)] = 0, 0.69,1) affect the structural role and redox state of Fe and melt viscosity.
Our experimental results show non-linear relation of log ($Fe2^{+}/Fe3^{+}$) vs. the alkali content, exhibiting a minimum at intermediate alkali ratio; mixing K and Na ions in the glasses produces deviations from linearity (mixed alkali effect). This observation parallels similar extrema found for the Ea of viscous flow of the same glasses. Changes in Fe oxidation state and alkali ratio also caused variations in the melt viscosity: decreasing $Fe2^{+}$/Fetot and Na/(Na+K) ratio results in viscosity increase of up to 1.5 log units. Moreover, there is still a need for new data for more accurately modelling the incorporation of H_2O in hydrous peralkaline magmas.
Hence, we carried out solubility experiments on hydrous samples with the aim to enlarge the experimental dataset and provide a deeper insight into the eruptive processes typical of these compositions.
Our results show that on a wt% basis, H_2O solubilities are significantly higher in peralkaline rhyolites in comparison with more common metaluminous rhyolites.

Comparing different numerical models for granular flows in volcanic areas

Francesco Neglia[1]*, Lucia Capra[2], Fabio Dioguardi[3], Roberto Sulpizio[1]

[1]Dipartimento di Scienze della Terra e Geoambientali, Università degli Studi di Bari, Bari, Italy
[2]Centro de Geociencias, Universidad Autónoma de México (UNAM), Mexico
[3]British Geological Survey, Edinburgh, UK
*Presenting author

The research on behavior of volcanic granular flows is one of the main topics in present day geophysics and volcanology. The vast interest is justified by the complex nature of these currents and by their very dangerous nature that threaten communities around active volcanoes and exposed to slope instabilities.
Granular flows can be defined as gravity-driven currents of solid particles in which the particle-particle interaction dominates the motion. In this category are included volcanoclastic debris flows triggered by prolonged rainfall. The aim of this work is to simulate these geophysical flows through numerical codes that numerically resolve the governing equations of the flow of granular material. For this study, we considered the following numerical codes: Titan 2D, VolcFlow and Flo2D. The numerical codes were applied to both natural and laboratory granular flows, in particular the block and ash flow of the 9th of June 2005 at Colima Volcano (Mexico), the volcaniclastic debris flows of the 5-6th May 1998 of Sarno (Italy) and some experimentally-generated granular flows with natural volcanic material carried out at University of San Luis Potosì (Mexico).
The application of different numerical codes to each considered case allowed us assessing strengths and weaknesses of the different codes. For each code, we also varied the rheological descriptions available, as to evaluate the rheological model that best fits experimental measurements and field data. Finally, sensitivity analyses were carried out using the flow runout and thickness of the deposits as benchmarks.

Textural analysis of some recent lavas of Ischia (Italy) from the last 10 k.y.

Francesco Calabria[1]*, Paolo Primerano[1], Guido Giordano[1], Alessandro Vona[1], Sandro de Vita[2]

[1]Dipartimento di Scienze, Università Roma Tre, Roma, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy
*Presenting author

The present work provides some important information to understand the emplacement of some recent lavas of Ischia from the last 10 k.y. Measuring the rheological parameters, such as the viscosity, it's possible to investigate the lava emplacement scenarios and, nonetheless, to evaluate the volcanic hazard of the island.
Two end members lavas were investigated, different for textural and compositional features: Zaro Lava (6 ± 2.2 k.y. ago) and Arso Lava (1302 A.C.). Starting from the Crystal Size Distribution (CSD), three differential growth events on two typologies of crystals (sialics and mafics) were recognised: phenocrysts, intermediate and a microcrystalline fraction interested by flow. For a better analysis, a 3-D disposition of the crystals was reconstructed on oriented thin sections of the Zaro lava by CSD. Samples were collected at different sites along the Unit: proximal, medial, and distal to the vent position. Several image acquisition techniques were used to acquire a full characterisation of the samples, such as scanning and SEM analysis, to investigate the crystals' distributions at various magnifications. The acquired images were edited and binarized by ImageJ software to have a wide distribution of the length of crystals' major axes compared to the total area fraction of each magnification.
A preliminary interpretation of these CSDs may suggest that microcrystalline fractions are affected by flowage and therefore they contributed to the total crystallinity during the lava emplacement. The microcrystalline fraction had grown in the stage that preceded the emplacement and cooling of the lava flow. After the quantification of the microcrystalline fraction, the samples were exposed to high temperature to reproduce a liquid/crystal condition similar to the lava emplacement. After estimating the temperature of lava emplacement, using high temperature uniaxial press, the final purpose of the work of measuring the viscosity value, has been achieved.

Lateral lava dome growth monitoring at Nevado del Ruiz Arenas crater using TerraSAR-X amplitude imagery

Erica De Paolo[1*], Thomas R. Walter[2], Edgar Zorn[2], Diego Coppola[3], Marco Laiolo[3], Francesco Massimetti[3], Maurizio Battaglia[1]

[1]Dipartimento di Scienze della Terra, Università Roma "La Sapienza", Roma, Italy
[2]GFZ German Research Centre for Geosciences, Physics of Earthquakes and Volcanoes, Germany
[3]Dipartimento di Scienze della Terra, Università di Torino, Torino, Italy
*Presenting author

Volcanic processes occurring in summit crater regions of steep volcanoes are often challenging to be monitored because of gas and ash or cloud coverage, impeding direct observations. Nevado del Ruiz, Colombia, hosts a strongly degassing crater with sporadic explosions and is covered throughout most of the year.
Using Synthetic Aperture Radar active systems we are able to look through these cloud layers, observing surface characteristics and deformation. High resolution amplitude imagery from satellites TerraSAR-X and TanDEM-X allowed to monitor the volcano unrest through almost four years. The presence of a small lava dome in crater Arenas since the end of 2015 has been identified. Dome growth tracking on image stacks reveals that dome expansion occurs mainly horizontally, with discrete phases of increased deformation rate. A comparison of the deformation trends with heat radiation measurements provided by MODIS-MIROVA system and Sentinel 2 images, confirms the presence of a thermal anomaly gradually evolving into ring shaped feature. To better comprehend this lateral growth and the development of such hotspots distribution we designed analog experiments using sandbox simulations of dome extrusion. We observe that the constant extrusion of granular material leads to dominantly lateral expansion after reaching a certain critical height. The horizontal spreading is therefore associated with gravitational adjustments represented by radial slumps of the slope. While the growth pattern is in line with the radar observations, the slope ruptures occurring around the flat-topped dome can be recognized in the late thermal anomaly patterns showing circular hot patches.
Investigating the mechanisms guiding lava domes evolution is crucial to assess the volcanic hazard, since their collapse potentially generate explosive eruptions or pyroclastic flows. For the first time, we are able to monitor stages of dome growth at Nevado del Ruiz volcano in detail.

Timescales of crystallization in basaltic magmas: effects of cooling and strain rates, preliminary results

Fabrizio Di Fiore[1]*, Alessandro Vona[1], Silvio Mollo[2,3], Claudia Romano[1]

[1]Dipartimento di Scienze, Università Roma Tre, Roma, Italy
[2]Dipartimento di Scienze Geologiche, Università di Roma "La Sapienza", Roma, Italy
[3]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Sismologia e Tettonofisica, Roma, Italy
*Presenting author

Extensive efforts have been made to experimentally determine the physico-chemical conditions driving the crystallization of natural basaltic magmas. A lot of experimental studies on intrusive and effusive volcanic rocks, performed in static conditions, have documented that the textural evolution and compositional changes of minerals are not necessarily related to the attainment of equilibrium, but rather to the development of reaction kinetics along most of the crystallization path of magmas. At the same time, only few works focused their attention on the role that dynamic conditions (i.e. presence of any kind of flow) play in the evolution path of a crystallizing magmas. In fact, magmas undergo a range of shear rates during transport and emplacement.
We present preliminary results of an experimental campaign conducted on a high-Mg basaltic magma.
Experiments were performed under different rates of cooling and strain, the latter reproduced through the stirring of the melt. Changes in the stirring conditions influence the ability of the lava to solidify during cooling path. In particular, the stirring affects the transport factor (i.e. diffusion) of chemical elements in the melt, the nucleation mechanisms, and the crystal growth. At large scale, the stirring drives the transport efficiency and eruption style that are governed by magma rheology (i.e. viscosity changes), evolving with cooling path, crystallization, and degassing.

Rheology and emplacement of a clastogenic lava flow: a natural case on Mount Etna

Alessandro Frontoni[1]*, Alessandro Vona[1], Guido Giordano[1], Marco Viccaro[2,3], Claudia Romano[1]

[1]Dipartimento di Scienze, Università degli Studi Roma Tre, Roma, Italy
[2]Dipartimento di Scienze Biologiche Geologiche e Ambientali, Università di Catania, Catania, Italy
[3]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy
*Presenting author

On the 18th May 2016 a lava-fountaining episode occurred from the crater Voragine of Mount Etna. After the filling of the summit craters Voragine and Bocca Nuova, a clastogenic lava overflowed from the western rim of the crater Bocca Nuova, flowing down on the western volcano flank and stopping at about 2000 m a.s.l. To describe the rheological behavior of the flow, a suite of high-temperature (1050 to 1100° C), uniaxial deformation experiments (strain rate 10-4 s^{-1}) have been performed on selected crystal- and vesicle-bearing natural samples, collected both in the crater area (loose scoriae samples) and along the lava flow (channel and lateral levees). Samples have been collected also at the front for what regards either the flow core or autobreccia clasts. Despite the different crystal contents shown by textural analysis, a progressive change in the rheological behavior has been recognized in agreement with the progressive increase in the vesicle content, which shows a maximum value for pyroclasts (56%) and varies from the inner part to the upper part (18-25%), reaching a minimum value in the intermediate portion (10%) of the lava flow. Preliminary rheological results of experiments performed at 3 different experimental temperatures and constant strain rate of 10-4 s-1, show that samples deform within the brittle regime at 1050° C, independently from their textural features and the portion of the lava flow in which they were collected. In contrast, with minor T increase (50° C), samples with high vesicle content maintain their brittle behavior, whereas in denser samples the ductile deformation dominates.
Combined textural and rheological data confirm field observations of the 2016 clastogenic lava flow. A marked decreasing in vesicle content from the pyroclasts to the overflowing zone due to sintering and compaction promoted lava viscous flow. Subsequently, the down flow porosity increase favoured the brittle behavior and autobreccia formation.

Understanding eruptive style changes at Fuego de Colima volcano (Mexico) by coupling numerical models and volcanological data

Silvia Massaro[1*], Antonio Costa[2], Roberto Sulpizio[1,3], Lucia Capra[4], Federico Lucchi[5], Diego Coppola[6]

[1]Consiglio Nazionale delle Ricerche CNR, Milano, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezone di Bologna, Bologna, Italy
[3]Dipartimento di Scienze della Terra e Geoambientali, Università degli Studi di Bari, Bari, Italy
[4]Centro de Geociencias UNAM, Campus Juriquilla, Queretaro, Mexico
[5]Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Università di Bologna, Bologna, Italy
[6]Dipartimento di Scienze della Terra, Università di Torino, Torino, Italy
*Presenting author

The Fuego de Colima volcano (Mexico) shows a complex eruptive behavior with periods of dome growth punctuated by mid- to high-intensity explosive eruptions. We investigated through physic-based numerical models two eruptive periods, as excellent examples of eruptive style transitions: the 1998-2015 activity and 1913 sub-Plinian eruption.
The numerical simulations are constrained by subsurface data and independently inferred volcanological information (mass discharge rates, erupted volumes). Two types of geometries are inferred for the conduit feeding system, with the reservoir located within elastic rocks at 6 km depth or a conduit fed by a dual, interconnected magma chambers located at 6 and 15 km depth. We demonstrated that the cyclic behavior of dome growth during 1998-2015 eruptive cycle depends on the intensity of influx rate, volumes of the magma chambers and their degree of connectivity. The single magma chamber model provides a good match with the observed mid-term periodicity (weeks) of dome extrusion, while the dual magma chambers model better describes the long-term periodicity (years). Concerning the transition from extrusive to explosive activity that led to the 1913 sub-Plinian eruption, we found two main mechanisms may be claimed: i) an increase in magma chamber overpressure (magmatic trigger) or ii) a decrease of lithostatic stress acting on the volcano (non-magmatic trigger). The former implies arrival into the chamber of a magma batch, whereas the latter requires decompression-induced emptying of the magma column within the conduit-feeding system.
A sudden jerk in lateral spreading is considered to be a reliable mechanism for unloading the upper conduit and driving fragmentation processes over a few hours. Results are still not conclusive between a magmatic or non-magmatic trigger of observed eruptive style transitions, but highlight the control of the different investigated processes on close-to-equilibrium volcanic systems.

Experimental model for lava fountaining: the case study of 26 January- 24 June at south east crater (Mt Etna, Italy)

Alessandro Musu[1]*, Daniele Morgavi[1], Laura Spina[2], Rosa Anna Corsaro[3], Diego Perugini[1]

[1]Dipartimento di Fisica e Geologia, Università di Perugia, Perugia, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Sismologia e Tettonofisica, Roma, Italy
[3]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy
*Presenting author

Basaltic volcanism provides up to the 70% of sub-aerial volcanic discharge. Is therefore not surprising the flourishing number of studies devoted to the investigation of the link between plumbing system dynamics and eruptive style.
Basaltic eruptive activity may range in a widespread spectrum from lava effusion up to rare violent Plinian eruptions. However, the most iconic explosive activities of basaltic volcanoes are represented by Strombolian explosions and lava fountains. To justify the onset, periodicity and the transition between the above mentioned eruptive styles, different hypothesis on the degassing dynamics have been made. Here, we make use of a laboratory volcano, Mt. Etna, to test the validity of these assumptions. In particular, we focus on an exceptional series of lava fountains observed in 2000 at South East Crater, with a multi-parametric approach. First, we investigate the pattern of geochemical data to infer the evolution of magmatic source. Thin sections from selected lava fountain episodes are analyzed and the correlations between the 2000 and the 2011-12 eruptions, which represent another incredible cyclic series of fountain activity, are also studied. Then, we assumed the collapse foam model CF [Jaupart and Vergniolle, 1989] as the reference source model for the 2000 eruptive sequence, and we looked for the best parameters that allows to fit the observed pattern and eruptive behavior (e.g. intermittence time, erupted volume of lavas etc.). Moreover, we performed several experiments using the experimental apparatus of Jaupart and Vergniolle [1988, 1989] having different viscosity from 0.001 Pas to 10 Pa s to constrain the effect of viscosity onto the rate of foam collapse. The experimental apparatus was reproduced in two different sizes in order to test the efficiency of the machine at different scales either with water or silicone oil.

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Parameterization of pyroclast cooling curves through infrared thermography.

Alex Scarani*, Aurora Silleni, Guido Giordano, Alessandro Vona, Claudia Romano

Dipartimento di Scienze della Terra, Università Roma Tre, Roma, Italy
*Presenting author

To better understand the temperature dynamics affecting pyroclasts during an explosive eruption, a suite of laboratory experiments was carried out with a thermal camera FLIR T 1030 on selected pyroclasts of variable porosity, dimension, and composition. Investigated samples include pumices and scoriae from the 4.1 ka Agnano Monte Spina (AMS, Campi Flegrei, alkali-trachyte) and 472 CE Pollena (PO, Vesuvio, tephritic phonolites) eruptions. Samples have a fixed shape (cubes with sides of 1.5 cm and 0.9 cm) and a porosity range (f) from 53-63% (PO) to 82-88% (AMS). Pyroclasts were heated up to 800° C and temperature variation was recorded during cooling in the air with a thermal camera and with two thermocouples placed inside the sample and next to its surface (used as external calibration temperatures).
The thermal loss was studied by combining temperature measurements from center, corner, vertex positions, and surface mean T of the clasts. Temperature-time plots indicate that differently from the usually adopted single exponential equation that defines the standard law of exponential decadence for cooling, T-t plots seem to be better reproduced by a double exponential equation.
Cooling behavior of investigated scoriae and pumices is strongly affected by clast dimension and porosity. In general, cooling efficiency increases with decreasing size and increasing porosity of the clasts.
Moreover, the influence of dimension seems to be more important for low porosity clasts, compared to high porosity ones where higher air entrainment allows more efficient cooling.

Investigating the thermal evolution of pyroclastic flows generated during the 1980 eruption of Mount St. Helens using paleomagnetic data

Matteo Trolese[1]*, Guido Giordano[1], Nick Pollock[2], Brittany D. Brand[2], Aurora Silleni[1], Francesca Cifelli[1], Massimo Mattei[1]

[1]Dipartimento di Scienze, Università Roma Tre, Roma, Italy
[2]Department of Geosciences, Boise State University, Boise, United States
*Presenting author

Although great efforts have been made on the study of pyroclastic density currents (PDCs), their thermal evolution and dynamics, and consequently their related hazard, still remain open issues; it is only with proper understanding of the mechanisms changing the thermal state of PDCs that a better predictive ability will emerge. The 1980 eruption of Mount St. Helens, USA, represents an excellent case study for examining how the temperature of the associated PDCs evolved along flow paths because observations and some direct temperature measurements were made. Here we will present results of an extensive paleomagnetic analysis on lithic clasts from these PDC deposits that provide important information about the entrainment and mixing efficiency of the current.

SESSION 3

Geology and structure of volcanoes

Convenors: Sandro De Vita and Federico Lucchi

The magmatological tectonics and volcanology: Alfred Rittmann's theories (1893-1980)

Daniele Musumeci[1]*, Stefano Branca[2], Luigi Ingaliso[1]

[1]Dipartimento di Scienze Umanistiche, Università di Catania, Catania, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania- Osservatorio Etneo, Catania, Italy
*Presenting author

Alfred Rittmann (1893-1980), founder of contemporary scientific volcanology, was a complete Earth scientist: petrographer, mineralogist, magmatologist, tectonist, planetologist, volcanologist. During sixty years of studies and research, the Basilian scientist produced more than 180 papers developing a complex and coherent scientific vision.
The volcanologist Rittmann needed to insert the volcanism within a general framework in the book "Vulkane und irhe Tatigkeit" (1936) discussing the first correlations between volcanism and tectonics. The research was then enriched with ideas about the structure and composition of the terrestrial interior and volcanism (1938-1939), the participation in the making of the Atlantic (1939); the theory on the pre-geological Earth's evolution elaborated together with the physicist W. Kuhn (1941), the theory on the orogeny and the temperatures distribution in the earth's crust (1942). The theory was supported by Rittmann for forty years through updates and kept up the new and decisive Plate Tectonics paradigm between the end of the 60s and 1981, when his last monograph was posthumously published. Leading concept of all geological processes is the fundamental law: each process is aimed at restoring an altered balance. The thermodynamic balance and a long series of geo-chemical-physical balances are the philosophical-scientific framework of the Rittmannian system.
We propose to name it magmatological tectonics and to describe it as a Kuhnian's paradigm (T. Kuhn 1922-1996). A volcanological and geological multidisciplinary approach corresponds to the achievement of a multiparametric volcanic monitoring that started on the slopes of Mount Etna in 1968 (International Laboratory of Volcanological Research) that is still operative, and has been operating for 50 years, with the current name Osservatorio Etneo-INGV of Catania.

Geological and structural evolution of Pleistocene La Reforma caldera complex, Baja California Sur, Mexico

Claudia Pellicioli[1,2*], Gianluca Groppelli[2], Roberto Sulpizio[2,4], Jose Luis Macías[3], Laura García Sánchez[3]

[1]Dipartimento di Scienze della Terra "Ardito Desio", Università degli Studi di Milano, Milano, Italy
[2]Istituto per la Dinamica dei Processi Ambientali -Sezione di Milano, CNR, Milano, Italy
[3]Instituto de Geofísica, Universidad Nacional Autónoma de México, Morelia, Michoacán, México
[4]Dipartimento di Scienze della Terra e Geoambientali, Università degli Studi di Bari Aldo Moro, Bari, Italy
*Presenting author

La Reforma is a 10 km wide nested caldera complex close to the Santa Rosalía town (Baja California Sur, Mexico). Pleistocene calc-alkaline volcanic activity moved from La Reforma to Sierra Aguajito and finally to Las Tres Vírgenes complex (currently hosting the fourth largest producing geothermal field).
The entire region is affected by an active transtensive tectonic regime (NW-SE trending right-lateral faults and NE-SW or N-S conjugate systems). Detailed field mapping and structural analysis performed across La Reforma caldera complex during 2015-17 allowed the reconstruction of its geological and structural evolution, highlighting the key role of faults in influencing the geometry of the caldera collapse and resurgence processes.
With regards to pre-, syn- and post-caldera activity, a volcanic edifice was built in a shallow marine setting during the pre-caldera phase (fossiliferous sediments interlayered with effusive and explosive activity products). The eruption of Los Balcones ignimbrite (1.35 Ma) triggered the formation of a caldera depression, that was then filled by lava flows alternated with scoriae and enlarged by La Reforma ignimbrite eruption (1.29 Ma). The trap-door geometry of the caldera collapse is due to the control of the prominent NW-SE Santa Ana fault that dissects the complex. The Punta Arena caldera-filling ignimbrite (0.96 Ma) closes the syn-caldera sequence. Effusive activity along ring faults and faults bordering the resurgent block, alternated with alluvial deposits produced by the dismantling of the uplifting resurgent-block, characterize the post-caldera phase. Resurgence occurred through several syn- and post-caldera uplift episodes and was strongly affected by regional structures, that isolated an asymmetric resurgent block (bordered by ring-faults only in its SE sector). Regional tectonics also played a primary role regarding hydrothermal fluid circulation, as revealed by overall low permeability of the volcanic area (0.002 -15 mD).

Caldera resurgence driven by magma viscosity contrasts

Federico Galetto[1]*, Valerio Acocella[1], Luca Caricchi[2]

[1]Dipartimento Scienze Università Roma Tre, Roma, Italy
[2]Department of Earth Sciences, University of Geneva, Geneva, Switzerland
*Presenting author

Calderas are impressive volcanic depressions commonly produced by major eruptions. Equally impressive is the uplift of the caldera floor that may follow, dubbed caldera resurgence, resulting from magma accumulation and accompanied by minor eruptions. Why magma accumulates, driving resurgence instead of feeding large eruptions, is one of the least understood processes in volcanology.
Here we use thermal and experimental models to define the conditions promoting resurgence. Thermal modelling suggests that a magma reservoir develops a growing transition zone with relatively low viscosity contrast with respect to any newly injected magma. Experiments show that this viscosity contrast provides a rheological barrier, impeding the propagation through dikes of the new injected magma, which stagnates and promotes resurgence.
In explaining resurgence and its related features, we provide the theoretical background to account for the transition from magma eruption to accumulation, which is essential not only to develop resurgence, but also large magma reservoirs.

Structural frame and volcano-tectonic evolution of the Campi Flegrei collapse caldera-resurgent dome system in the Pozzuoli bay based on multiscale seismic profiles analysis

Jacopo Natale[1]*, Luigi Ferranti[1], Camilla Marino[1], Marco Sacchi[2]

[1]Dip. di Scienze della Terra, dell'Ambiente e delle Risorse (DiSTAR), Università "Federico II, Napoli, Italy
[2]Istituto per l'Ambiente Marino Costiero (IAMC), Consiglio Nazionale delle Ricerche (CNR), Napoli, Italy
*Presenting author

The present study aims at contributing to the structural framework and volcano-tectonic evolution of the Campi Flegrei caldera with a joint analysis of multi-scale seismic profiles in the Pozzuoli Bay, providing additional insights into the last ~15 ky of ground deformation. Only in recent years the submerged part of the caldera has been explored using marine geophysical data [Sacchi et al., 2014; Steinmann et al., 2016, 2018]. Seismo-stratigraphic interpretation of the marine geophysical data revealed that, after the NYT eruption, rejuvenation of the activity occurred mainly along the ring faults while a resurgent central dome system was gradually developing.
The shallowest seismo-stratigraphic interval has been calibrated by marine gravity cores which allowed to identify key horizons between the AD 1538 Monte Nuovo tephra to Nisida tephra ~3.9 ky. Chronostratigraphy of the deeper part of the caldera infill sequence has been inferred through tentative correlation with the most significant eruptions known on-land taking into account vent location, VEI, distribution of pyroclastic deposits and hiatuses developed during periods of relative volcanic rest [Smith et al., 2011]. Moreover, the depositional environment has been affected by post-glacial sea-level rise as reconstructed by Lambeck et al. [2011].
This work provides a first detailed map of faults developed on top of the resurgent dome and an improved characterization of the ring faults, on the southern side of the caldera. The apical faults of the dome have a complex pattern with NNE-SSW dominating trend. Since ~12 ky a total uplift of ~130 m is estimated between the post collapse un-deformed and dome-deformed markers. On the eastern side of the gulf has been defined timing and extension of a laccolite intrusion. On the western side, the Punta Pennata structure has been mapped and interpreted as a localized structure linked to magma migration in the footwall of the collapse ring fault.

Vertical deformation of the Campi Flegrei caldera (Pozzuoli Bay) during the last 12 ky through analysis of seismostratigraphical and geomorphological sea-level markers

Camilla Marino[1]*, Luigi Ferranti[1], Jacopo Natale[1], Marco Sacchi[2]

[1]Dip. di Scienze della Terra, dell'Ambiente e delle Risorse (DiSTAR), Università Federico II, Napoli, Italy
[2]Istituto per l'Ambiente Marino Costiero (IAMC), Consiglio Nazionale delle Ricerche (CNR), Napoli, Italy
*Presenting author

A seismic stratigraphic analysis of very high-resolution seismic profiles provided insights into the last ~12 ky vertical deformation pattern in the submerged part of the Campi Flegrei resurgent caldera, in the Pozzuoli Bay.
Interpretation of the dataset acquired during the oceanographic survey SEISTEC_2013, calibrated by marine gravity cores, allowed us to identify key seismic horizons characterized as tephras between the 1538 AD and ~3.9 ky eruptions. The chronostratigraphy of the older part of the caldera infill was inferred through tentative correlation between the most evident horizons and the most significant known eruptive events. The depositional environment has been significantly affected by sea-level variations. Seismic stratigraphic interpretation reveals the occurrence during the last ~12 ky of several generations of Infralittoral Prograding Wedges (IPW). IPW's edge (the inflection point) can be considered as proxies for the position of the past sea-level and used to reconstruct the evolution of vertical deformation. Correction of the observed depth of each IPW for the paleo-bathymetric estimate and for the sea-level change, allowed to reconstruct differential RSL curves for the western, central and eastern sector of the submerged caldera.
Results of this work indicates a variable development of IPWs between sectors as a result of dome resurgence and collapse allowing to recognize different trajectories of the IPW edge and at least four types of stacking pattern: a) IPWs with a descending trajectory, forming during known phases of volcanic unrests with a prevalence of uplift over the sea-level rise; b) IPWs with a flat trajectory, indicating pure progradation during a relative sea-level still-stand where the uplift kept pace with the sea-level; c) Prograding/aggrading bodies with an ascending trajectory, developing at the end or at the beginning of an unrest phase; d) Pure aggrading bodies indicative of subsidence are coeval to periods of quiescence.

Palaeomagnetic Dating of the Neostromboli Succession

Gilda Risica[1,2,3*], Fabio Speranza[2], Guido Giordano[4], Gianfilippo De Astis[2], Federico Lucchi[5]

[1]Università degli Studi di Firenze, Dipartimento di Scienze della Terra, Firenze, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Geomagnetismo, Aeronomia e Geofisica Ambientale, Roma, Italy
[3]Università di Pisa, Dipartimento di Scienze della Terra, Pisa, Italy
[4]Università degli Studi di Roma Tre, Dipartimento di Scienze, Roma, Italy
[5]Università di Bologna, Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Bologna, Italy
*Presenting author

The Neostromboli volcanic succession is characterized by packages of lava flow units and scoria beds erupted from the summit of the Stromboli volcano, and by scoria cones and flows poured out from lateral vents and fissures.
Available radiometric ages constrain Neostromboli activity in the 14-4 ka age window, but the chronological relations of central vs. peripheral activity are still poorly understood. Furthermore, radiometric and palaeomagnetic ages of some of the peripheral eruptions are strikingly inconsistent. Here we report on the palaeomagnetic dating of thirty-four sites from Neostromboli products. Seventeen are new palaeomagnetic directions, while additional seventeen ages are recalculated - using published directions by Speranza et al., [2008] - with the recent SHA.DIF.14K paleo-secular variation (PSV) field model. We show that the beginning of Neostromboli succession could be much younger than the commonly accepted ≈14 ka onset, providing our oldest data an age of ≈9 ka. The improved geochronological resolution allowed by palaeomagnetic dating suggests that the early stages of the Neostromboli activity occurred at 9-8 ka and were characterized by summit lava flow units blanketing both the SW and northern volcano flanks; after ≈7.5 ka lateral eruptions became dominant from peripheral cones and fissures.
We suggest that the intense flank activity enabled magma-water interaction thus yielding explosive activity and repeated collapse events, leading to the Sciara del Fuoco formation. Our work confirms that PSV analysis of Holocene volcanics may yield eruption chronology definition with an accuracy unlikely to be achieved with other radiometric techniques.

Criteria models of shear deformation along the southern margin of unstable eastern flank of Mt. Etna

Giorgio De Guidi, Giuseppe Morreale, Giuseppe Marsala, Francesco Carnemolla*, Fabio Brighenti

Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Sezione di Scienze della Terra, Università degli Studi di Catania, Catania, Italy
*Presenting author

The eastern slope of Mt. Etna is characterised by shallow seismicity originating from normal-oblique faulting, Timpe fault system, related to WNW-ESE regional extension. Several interpretations of the unstable eastern flank indicate a simple gravity-controlled mechanism enhanced by magmatic intrusions. Conversely some Authors indicate one or more causative factors or interaction between them (regional stress, gravity and dike-induced rifting) to produce the slow sliding of eastern flank of the volcano.
Two geodetic subnetworks were established in 2010 and in 2014, along the southeastern edge of the unstable eastern flank of Mt. Etna volcano. These networks have been surveyed since late 2014 with GNSS techniques. According to some Authors, the time–space boundaries of the lateral sliding, which is probably much younger and shallower than is generally stated and differentially involves distinct blocks, remains to be constrained more accurately. The resulting horizontal velocity field [De Guidi et al., 2018] allowed us to observe a westward decay of the rate and a different azimuthal pattern of motion between the western and the eastern network. In this study we distinguish near southern boundary (Tremestieri-San Gregorio-Acitrezza fault zone) of unstable eastern slope, four distinct blocks, characterised by different strike and modules of velocity, separated by active fault segments characterised by different kinematics.
We suggest that shallower sliding of eastern Etna slope could be explained invoking the criteria models of shear deformation at different depth and temperature. The amount of stress field related to terrain mechanical parameters affected by shear fault segments, has been estimated in order to provide useful indications.

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The interaction between faults and volcanic systems in extensional areas

Ada De Matteo[1*], Giacomo Corti[2,3], Benjamin van Wyk de Vries[4], Bruno Massa[1,5], Giulio Mussetti[6]

[1]Università degli Studi del Sannio, Dipartimento di Scienze e Tecnologie, Benevento, Italy
[2]Consiglio Nazionale delle Ricerche (CNR), Istituto di Geoscienze e Georisorse (IGG), Sede Secondaria di Firenze, Italy
[3]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Pisa, Italy
[4]Université Clermont Auvergne, Observatoire du Physique du Globe de Clermont, Laboratoire Magmas et Volcans, UMR6524-CNRS, France
[5]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy
[6]Università degli Studi di Firenze, Dipartimento di Scienze della Terra, Firenze, Italy
*Presenting author

Areas undergoing pure extension are typically characterized by the formation of faults and fractures orthogonal to the maximum principal stress. In such areas, the presence of a volcano and its magmatic system can perturb the local stress field, leading to changes in faulting magnitude and attitude. Interaction of tectonic stresses with volcanic edifices and magma chambers has been analyzed in many previous modeling works, in which fault-volcano interaction have been reproduced with set ups that create extension over a single discontinuity by use of a standard base plate. However, many natural rifts display broadly distributed extension between main border faults, with no discrete discontinuities driving deformation. To account for these conditions, we improved the previous works by reproducing and analyzing the interaction of tectonic stresses with volcanic edifices in areas characterized by broadly distributed extension. With this improved set up, models better reproduce the geometry and architecture of faulting in rifts, leading to improved results to compare with real cases. We confirmed that the presence of a volcano and/or an intrusive body locally modifies the fault pattern, concentrating faulting and curving faults. Notably, the rheological contrast between the intrusion and the host rock leads to faults that follow the outline of the body, favoring concentric faults. In contrast radial faults are developed by the volcano load. The geometry of the resulting faults is dependent on the coexistence (or not) of intrusion and edifice and on their dimensions. The results indicate that volcanic edifices have a stronger influence on fault attitude with respect to the presence of intrusions. Experimental results are compared with some natural cases from the East African Rift System.

The volcanic fingerprint in the sand of the Ofanto River (Southern Italy)

Mariano Tenuta*, Domenico Parise

Dipartimento di Biologia, Ecologia e Scienze della Terra, Università della Calabria, Rende, Italy
*Presenting author

The Ofanto River drains several litologies, including volcanic rocks from the Mt. Vulture, lacustrine–fluviolacustrine deposits associated to the same volcano, and sedimentary deposits of the Southern Apennine and of the Bradanic Foredeep. As a result, the Ofanto basin represents a good case study to understand how a volcanic complex can influence the sand composition. A granulometric, compositional and microanalytical study was carried out on the sand of the Ofanto River and its tributaries, in order to detail provenance and dispersion of the volcanic fraction. The microanalytical study revealed that the composition of the volcanic minerals (mainly pyroxene, melanite garnet and Mg-hastingsite amphibole) is identical to that of the same minerals of Mt. Vulture volcanics, although, especially in the upstream, a possible provenance from explosive eruptions of the Somma- Vesuvius and/or Campi Flegrei cannot be excluded. The modal analysis showed that the volcanic component is abundant not only in the samples picked up where the volcanics represent an important portion of the drained sub-basin, but even in points where the volcanic rocks do not outcrop and only few volcaniclastic layers in old lacustrine–fluviolacustrine basins associated to the Mt. Vulture occur.
This can be explained with the high sand production of these reworked volcanics, together with the lability of the carbonate grains and the low sand-sized detritus production of clays and marls. The results of this study show that sedimentary basins with small amounts of volcaniclastic material can produce sediments with an amount of volcanic component comparable to that produced by the erosion of volcanic rocks.
Therefore, caution must be taken during paleo-environmental reconstructions when relating the volcanic component of a sediment to the presence of a paleo-volcano.

SESSION 4

Monitoring and volcanic risk

Convenors: Ornella Cocina and Giovanni Macedonio

Thermally induced signals in closed-conduit volcanoes: a reappraisal of geochemical and geophysical data of 1988 unrest at La Fossa cone (Vulcano Island, Italy)

Mirko Messina[1*], Carmelo Ferlito[1], Mario Mattia[2]

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

Since the end of the last eruption (during the biennium 1888-1890), Vulcano is going through a quiescent phase. In 1988, the island of Vulcano underwent a significant unrest, during which all the recorded parameters showed the most important variations since the last critical episode (occurred in 1924). In particular, the temperature recorded at the fumarolic field, located on the crater rim, reached the highest value of 700° C. Also the amount of gases discharged from the crater's fumaroles increased by one order of magnitude. Analyzing four different gases (H_2O, CO_2, SO_2 and H_2S) we've estimated the heat flux carried by these gases during the unrest and during a normal-degassing phase, noting a 100% increase in the total energy released during the unrest (from $2.8 \cdot 10^{11}$ J/d to $5.6 \cdot 10^{11}$ J/d). Here, the data from the different volcanological and geophysical observation techniques are reanalyzed in order to evaluate the possibility that the unrest could have been triggered by a significant variation in the flow of magmatic gas and the relative increase of the temperatures recorded in the fumaroles, without any direct involvement of magma. In particular, the important phase of deflation [Bonaccorso, 2002] observed during the period 1988-1990 by means of geodetic measurements of soil deformation, testifies, in our opinion, the overheating and the subsequent evaporation of fluids present inside the important hydrothermal system below La Fossa crater of Vulcano. This model also represents an interpretative key for the phenomena of variation of the geophysical and geochemical parameters observed at Vulcano.
Finally, in order to evaluate any analogies with other volcanoes with characteristics similar to those of Vulcano, a comparison of the monitoring parameters and their possible interpretation is proposed, in light of the importance of the link that emerges from our model between unrest phases and variations in gaseous and heat flows.

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Evaluation of deep carbon dioxide emissions from soils on Vulcano Island

Roberto Maria Rosario Di Martino*, Giuseppe Capasso, Marco Camarda

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Palermo, Italy
*Presenting author

The carbon dioxide emissions of volcanoes have been targeted as effective contributors of CO_2 to the atmosphere. However, different sources can be effective and active at the same time in the generation and release of CO_2 in volcanic zones. Since isotopic fingerprinting of CO_2 allows the precise identification of different sources, coupling carbon isotope and CO_2 flux measurements enables the evaluation of the mass contribution of each source to the carbon dioxide emissions.
This work accounts for the first extensive spatial analysis of coupled measurements of carbon isotopologues of CO_2 in the soil gases and CO_2 fluxes discharged by soils on Vulcano Island. An innovative method has been designed, tested and fine-tuned in the laboratory to measure $\delta^{13}C(CO_2)$ values directly in field using a new type of laser-based isotopologues analyser, namely a DeltaRayTM (Thermo Fisher Scientific). The method has been used to determine the carbon isotope composition across the full range of CO_2 concentrations in the soil gases (0 -100 vol %). These data have been combined with measurements of the CO_2 contents in the soil gases to distinguish CO_2 of deep origins from CO_2 of biogenic origin in the inhabited area of Vulcano Porto. The method of evaluating the amount of deep-origin CO_2 in the soil gases is widely applicable in volcanic and geothermal zones for evaluation and monitoring purposes volcanoes.

Understanding the SO_2 degassing budget of Mt Etna's paroxysms: first clues from the December 2015 sequence

Roberto D'Aleo[1]*, Marcello Bitetto[2], Dario Delle Donne[3], Mauro Coltelli[4], Diego Coppola[5], Brendan McCormick Kilbride[6], Emilio Pecora[4], Maurizio Ripepe[7], Salem Lois[6], Giancarlo Tamburello[8], Alessandro Aiuppa[2]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Palermo, Italy
[2]Dipartimento DiSTeM, Università degli Studi di Palermo, Palermo, Italy
[3]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy
[4]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Catania, Italy
[5]Università degli Studi di Torino, Torino, Italy
[6]COMET, Department of Earth Sciences, University of Cambridge, United Kingdom
[7]Università degli Studi di Firenze, Dipartimento di Scienze della Terra, Firenze, Italy
[8]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Bologna, Italy
*Presenting author

Direct measurements of a paroxysm's gas flux budget of open-vent basaltic volcanoes have remained challenging to date, although the magmatic gas is unquestionably the drivers of these events.
A particularly violent paroxysmal sequence took place on Etna on December 2015, intermittently involving all summit craters, especially the Voragine (VOR) that had previously displayed no activity for several years. Here, we characterize the volcano's SO_2 degassing budget prior to, during and after this paroxysmal sequence, using ground-based (UV-Camera) and satellite (OMI) observations, complemented with ground- and space-borne thermal measurements. We make use of the high spatial resolution of UV-cameras to resolve SO_2 emissions from the erupting VOR crater for the first time, and to characterize temporal switches in degassing activity from VOR to the nearby New Southeast Crater (NSEC). Our data show that onset of paroxysmal activity on December 3-5 was marked by visible escalation in VOR SO_2 fluxes (4700-8900 tons/day), in satellite-derived thermal emissions (2000 MW vs. ~2-11 MW in July-November 2015), and in OMI-derived daily SO2 masses (5.4±0.7 to 10.0±1.3 kilotonnes, kt). Switch in volcanic activity from VOR to NSEC on December 6 was detected by increasing SO_2 fluxes at the NSEC crater, and by decaying SO_2 emissions at VOR, until activity termination on December 19. Taken together, our observations infer the total degassed SO_2 mass for the entire VOR paroxysmal sequence at 21,000±2730 t, corresponding to complete degassing of ~1.9±0.3 Mm^3 of magma, or significantly less than the measured erupted magma volumes (5.1-12 Mm^3).
From this mismatch we propose that only a small fraction of the erupted magma was actually emplaced in the shallow plumbing system during (or shortly prior) the paroxysmal sequence. Rather, the majority of the erupted magma was likely stored conduit magma, having gone through extensive degassing for days to weeks prior to the paroxysm.

Concentration transients of H_2, CO_2, He of volcanic gases

Roberto Maria Rosario Di Martino*, Marco Camarda, Sergio Gurrieri

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Palermo, Italy
*Presenting author

A thorough understanding of gas transport dynamics is of considerable interest in volcano monitoring. Despite it is well recognized that magmatic gases percolate through a volcano's flank to the surface, how diffuse gases move through the ground is currently a concern in Volcanology.
Here, we show a theoretical model which accounts for the compositional changes in gases passing through soils. In the theoretical framework, a homogeneous porous medium separates the gas reservoir from the Earth's surface. The model includes the effects of both diffusive and advective transport processes and achieves a mathematical solution to the fluid flux problem through the approximate analytical approach of the integral method. Moreover, a gas flux experiment has been designed to check the reliability of the theoretical computations. In this experiment, the flux tests were performed with pure CO_2, He, and several laboratory gas standards, which were composed of the gas components emitted in volcanic areas. The agreement between the theoretical calculations and the experimental results supports the validity of the model.
Our results indicate a good reproducibility of the transient changes in the concentrations of H_2, CO_2 and He in CO_2-rich gas mixtures that contain He and H_2 as trace gases. Finally, the theoretical results were used to analyse the H_2 and CO_2 continuous monitoring data collected at Etna volcano in 2010.

Geo-referencing techniques of 3d models (SfM): Case study of mud volcano, Villaggio Santa Barbara (Caltanissetta)

Fabio Brighenti*, Francesco Carnemolla, Danilo Messina, Giorgio De Guidi

Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali- Sezione di Scienze della Terra, Catania, Italy
*Presenting author

In the last 2 years we have performed a topographic and geodetic monitoring on an active mud volcano located in central Sicily (Caltanissetta, Terra Pelata locality). The target was to understand how the volcano is evolving morphologically and kinematically. Topographic and geodetic surveys were performed periodically (every 3 months) by using a suite of double-frequency GNSS receivers that where been set-up to monitor the kinematics and to geo-reference cartographic products (DTM, DSM and orthophotos). Digital maps were realized through photogrammetry technics and 3D surface modelling by adopting Structure for Motion (SfM) algorithm.
Following the aim, morphological variations due to active tectonics and/or ground movements which deform the area were achieved. The monitoring network has been deployed following a twofold target. The first one, is to observe the deformation and kinematics of the area surrounding the mud volcano. To do this, we fixed a stable benchmark by building a GNSS base and surveys were hence performed with a static D-GNSS. This configuration allows us to obtain a sub-centimetre precision in the point location. Other six points were also built and connected to the base. The second was to georeferencing, with high-precision, a series of ground control point (from now on GCPs) to positioning 3D surface model. Our data show that the combination of TST with GNSS provides a greater precision in geo-referencing digital maps even if it requires a long acquisition time. The results, coming from the monitoring, allow us to quantify volumetric and altimetry changes of the mud volcano which are in the order of ± 1 dm during inflection or deflection phases. Our data suggest that the surface of mud volcano is experiencing a general trend of uplift in the order of one decimetre.
The methods applied in this work to improve the positioning of objects in remote sensing techniques such as rock clusters, landslides, active structures and volcanic risk.

Non-eruptive unrest at the caldera of Alcedo Volcano (Galápagos Islands) revealed by InSAR data and geodetic modelling

Federico Galetto[1*], Marco Bagnardi[2,3], Valerio Acocella[1], Andy Hooper[2]

[1]Università degli Studi di Roma Tre, Dipartimento di Scienze, Rome, Italy
[2]COMET, School of Earth and Environment, University of Leeds, Leeds, UK
[3]Now at Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
*Presenting author

Understanding volcanic unrest is crucial to forecasting eruptions. At active mafic calderas, unrest usually culminates in eruption, and does so more frequently than at felsic calderas. However, the mafic caldera of Alcedo Volcano (Ecuador) has experienced repeated episodes of unrest without erupting, since at least 1992, when geodetic monitoring began. Here, we investigate the unrest occurred between 2007 and 2011 performing a multi-temporal InSAR analysis of ENVISAT and ALOS-1 data, using the Small Baseline method. Then, we inverted ALOS-1 data to constrain the sources of deformation, using the GBIS software. We observe an initial asymmetric uplift of the caldera (~30 cm of vertical motion) from 2007 to 2009, followed by subsidence of the uplifted area and contemporary uplift of the north-western caldera rim between January and June 2010.
Finally, from June 2010 through March 2011, caldera uplift resumed. The first uplift episode is best explained by inflation of a sill and the activation of an inner ring fault. Successive caldera subsidence and rim uplift are compatible with the withdrawal of magma from the previously inflated sill and its north-western migration. The resumption of uplift is consistent with the re-pressurization of the sill. This evolution suggests episodic magma emplacement in a shallow reservoir beneath the caldera, with aborted lateral magma migration, probably due to the discontinuous supply from depth. This short-term deformation pattern matches well geological observations showing a longer-term (hundreds of years at least) asymmetric uplift of the caldera floor, culminating in a weak resurgence of ~30 m. We propose that the monitored episodes of uplift represent short-term stages of the rarely observed incremental growth of a resurgent basaltic caldera.

Block-and-ash flow and related ash-cloud, how hot they can be? Temperature estimations from the July 2015, Volcàn de Colima dome collapse deposits

Alessandra Pensa[1,2]*, Lucia Capra[2], Guido Giordano[1]

[1]Dipartimento di Scienze della Terra, Università Roma Tre, Roma, Italy
[2]Centro de Geociencias, Universidad Autónoma de México (UNAM), Mexico
*Presenting author

Temperature estimations of the block-and-ash flow and ash-cloud developed during the 2015 dome collapse at Volcán de Colima, Mexico, were performed using Reflectance analysis and micro-tomography images processing of pine wood charred fragments. The combination of these two independent and well-established methods to organic matter charred in a volcanic environment constitutes a pioneering attempt for the indirect temperature estimation of both dense and dilute pyroclastic density currents (PDCs). Wood fragments at different heights along tree trunks were sampled in order to detect temperature variations, not only from proximal to distal area, but also to distinguish between the portions affected by the dense basal block-and-ash flow and those by the overriding ash cloud.
The results obtained from charred wood Reflectance analysis confirmed by micro-tomography image analysis highlighted temperature difference from the lower (Zone A) to the upper trees portion (Zone B).The results of vertical and horizontal temperature variations have been discussed in relation to the block-and-ash flow and the over-riding ash cloud flow dynamics and their interaction with the topography confinement along the Montegrande ravine. The temperature variation maps finalized in this study for both dense and diluted pyroclastic flows, have important implication in terms of hazard assessment for pyroclastic flow events along narrow valleys that usually cut the steep slopes of stratovolcanoes.

Hg and CO_2 emissions from soil diffuse degassing and fumaroles at Furnas Volcano (São Miguel Island, Azores): Gas flux and thermal energy output

Emanuela Bagnato[1*], Fatima Viveiros[2,3], Eduardo J. Pacheco[2,3], Fabio D'Agostino[4], Catarina Silva[2,3], Vittorio Zanon[2,5]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Napoli, Italy
[2]Instituto de Investigação em Vulcanologia e Avaliação de Riscos (IVAR), Universidade dos Açores, Portugal
[3]Centro de Informação e Vigilância Sismovulcânica dos Açores (CIVISA), Portugal
[4]Institute for Coastal Marine Environment (IAMC) -CNR, Torretta Granitola, Italy
[5]Institut de Physique du Globe de Paris, Université Sorbonne Paris Cité, Université Paris Diderot, CNRS UMR-7154, Paris, France
*Presenting author

Volatiles release from active degassing areas contributes to the long-term trace metals budget to the atmosphere. Mercury (Hg) emissions from active degassing areas are of interest for estimating the volcanogenic contribution to the global atmospheric Hg budget. Most of the Hg initially present in the magma, seems to be released to the atmosphere as gaseous elemental mercury (GEM) during the early stage of degassing. GEM and CO_2 are emitted from active hydrothermal systems in volcanic areas mostly through diffuse degassing. A survey of about 400 simultaneous measurements of soil GEM and CO_2 flux has been performed within the caldera of Furnas Volcano, São Miguel Island (Azores) aimed at providing a new insight into the origin and magnitude of GEM in the investigated hydrothermal/volcanic environment and its relation with CO_2 release. We found that the distribution of GEM and CO_2 emissions over an area of about 0.04 km2 is correlated with soil temperature, and measurements have provided total CO_2 and GEM output of 39 t d^{-1} and 1.8×10^{-6} t d^{-1}, respectively. These results are similar to the emission from currently active volcanic/hydrothermal areas elsewhere, as well as from important non-volcanic areas, such as Sulphur Bank Mercury Mine (California, USA) and Idrija Mercury Mine (Slovenia, EU), pointing out the relevance of diffuse degassing processes at Furnas Volcano. Atmospheric spot measurements in the most vigorous fumarole vents of the geothermal field have shown that the fumarolic GEM contribution (9.2×10^{-7} t d^{-1}) represents a minor fraction of the total (fumarolic+diffusive) GEM output (2.7×10^{-6} t d^{-1}) for the study area of this volcano. Basing upon the integration of the hydrothermal CO_2 released and the H_2O/CO_2 ratio in the fumarolic gas, we have also estimated the thermal energy release associated with diffuse degassing at Furnas Volcano. Our estimates are 7.8 MW and 9.8 MW, respectively for Furnas Lake and Furnas Village fumaroles.

Monitoring of post-seismic deformation of the Fiandaca-Pennisi shear-zone (M. Etna volcano Sicily). The case of seismic swarm of 26th December 2018

Fabio Brighenti*, Francesco Carnemolla, Claudia Arcifa, Filippo Aiozzo, Giuseppe Altara, Francesco Cavalli, Maria Chiara Donato, Nency Dottore, Anna Figlioli, Francesco Furia, Gregory Giammusso, Salvatore Giuffrida, Orazio La Rosa, Federico Latino, Danilo Messina, Mirko Messina, Nadia Mortellaro, Dario Petrone, Davide Russo, Gaia Sacco, Stefano Sardone, Francesco Scaletta, Benedetta Scandurra, Giuseppe Sineri, Federica Sozzi, Giorgio De Guidi

Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali- Sezione di Scienze della Terra, Catania, Italy
*Presenting author

The aim of this work is to provide the results of the monitoring activity of the fracturing field developed during the seismic event occurred 48 hours after the short but intense flank eruption of Etna volcanic complex. The eruptive event was developed from SE crater base of Mt. Etna from 24 till 27 December 2018. The NNW-SSE eruptive fracture represents the surface on the surface of the hydrofracture feeding system, which probably affected the entire structural frame of the Etna eastern flank, reactivating Fiandaca-Pennisi shear zone [Monaco et al., 2010]. During the seismic swarm, the maximum magnitude (ML 4.9) was recorded at 3.19 AM, 2 km N away from Viagrande (CT) with a depth of 1.0 km [http://cnt.rm.ingv.it/event/21285011]. The fracturing field was recognized by geological maps [Monaco et al., 2010; Branca et al., 2011] and field survey, collecting the geometrical and kinematics parameters related to the shear segments. GEOmatic lab. The GEOmatic lab, assisted by the UniGeoCt students, have structured and defined along the deformation zone, the array of benchmarks belonging to UNICT network [De Guidi et al., 2018]. Our purpose is to evaluate post-seismic deformation processes of 12th December 2018.
The first measure has made on 12th December 2018; 4 benchmarks have been placed respectively in the southern and northern part of the system. Additional points and new geodetic-topographic measurement will be done. The focus is to characterize the post-seismic deformation processes and identify the real belt of Fiandaca-Pennisi shear zone in order to provide further detailed information useful to the Civil Protection, INGV and University Institutions.

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Structural field survey of Fiandaca - Pennisi shear zone (Mt. Etna volcano) affected by seismic swarm occurred on 26th December 2018

Fabio Brighenti*, Francesco Carnemolla, Francesco Furia, Martina Occhipinti, Francesco Romeo, Gaia Sacco, Mariabenedetta Scandura, Giorgio De Guidi

Università di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali - Sezione di Scienze della Terra, Catania, Italy
*Presenting author

This work introduces the results of geological survey along the fracturing field developed during the seismic event occurred 48 hours after the short but intense flank eruption of Etna volcanic complex. The eruptive event was developed from SE crater base of Mt. Etna from 24 till 27 December 2018. The NNW-SSE eruptive fracture represents the surface on the surface of the hydrofracture feeding system, which probably affected the entire structural frame of the Etna eastern flank, reactivating Fiandaca-Pennisi shear zone [Monaco et al., 2010].
During the seismic swarm, the maximum magnitude (ML 4.9) was recorded at 3.19 AM, 2 km N away from Viagrande (CT) with a depth of 1.0 km [http://cnt.rm.ingv.it/event/21285011]. The fracturing field was recognized by geological maps [Monaco et al., 2010; Branca et al., 2011] and field survey, collecting the geometrical and kinematics parameters related to the shear segments. The trend deformation field was observed from Acireale area (NNW-SSE strike) to Fleri area (WNW-ESE strike) near Mt. Ilice. The deformation area is about 6 km length and width ranging from few meters to hundreds. During field survey, Fractures measured have been interpreted as Riedel's R or T type fractures in a right lateral shear zone [Riedel, 1929]. The results of this work will allow us to define the areas vulnerable to structural deformation affected by superficial earthquakes, which usually happen on the Etna volcanic complex [De Guidi et al., 2012]. In conclusion this work is aimed to better define risk areas for population and anthropic structures, useful for official istitutions. (Civil Protection, National Institute of Geophisics and Vulcanology (INGV), University Institutes).

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Characterization of volcanic ashes in cores from the Bransfield Strait and their correlation with volcanic eruptions from Deception Island, Antarctica

Joaquin Hopfenblatt[1*], Meritxell Aulinas[1], Adelina Geyer[2]

[1]Dept. MIneralogia, Petrologia i Geologia Aplicada (Universitat de Barcelona), Barcelona, Spain
[2]Institute of Earth Sciences Jaume Almera (ICTJA-CSIC), Barcelona Spain
*Presenting author

The study of volcanic ash (tephrochronology) is a very powerful tool that requires tephra characterization for dating or linking different events, like volcanic eruptions. The aim of this work is the description and analysis of volcanic ash samples in marine sediment cores located at the Bransfield Strait. For such purpose, volcanic ash from five cores located close to Deception Island are geochemically and morphologically characterized.

In order to carry out the morphological characterization, selected samples were studied with petrographic microscope and scanning electron microscope (SEM). Particle size distribution was done by dry sieving. Geochemical analysis of mineral phases and glass were performed with electron microprobe (EMP).

The morphological results show grains size that vary from fine ash to lapilli and two types of morphology: blocky and curve. The petrographic results show four types (I, II, III and IV) of ash fragments.

With regard to their chemistry, glass compositions are similar in the four types of fragments being mainly classified as basaltic andesite and basaltic trachyandesite, whereas, mineral phase compositions are more variable. Plagioclases range from andesines to bytownites with An36-86, pyroxenes are mostly augites with Wo29-44, En36-55, Fs11-21, diopsides with Wo45-46, En39-41, Fs12-15 and minor pigeonites with Wo5-6, En55-66, Fs29-40. Olivines show a wide variety of chemical composition with Fo58-85.

The chemical composition of glass is very similar to those displayed by the post-caldera stage in Deception Island [Geyer et al. in press] except for SiO_2, which is lower. Yet, both exhibit the same magmatic evolution trend. These results suggest that the studied ash samples could represent older magmas erupted earlier in the post-caldera stage. Mineral chemistry of ash samples reported in this work is also very similar to those displayed by post-Caldera Deception samples. This research was supported by de MICINN projects POSVOLDEC (CTM2016-79617-P) (AEI/FEDER, UE) and VOLCLIMA (CGL2015-72629-EXP) (AEI).

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Results from high resolution SENTINEL-2 and MODIS-MIROVA satellite thermal signals at Stromboli and Etna volcanoes

Francesco Massimetti[1*], Diego Coppola[1], Marco Laiolo[1], Corrado Cigolini[1], Maurizio Ripepe[2]

[1]Dipartimento di Scienze della Terra, Università di Torino, Torino, Italy
[2]Dipartimento di Scienze della Terra, Università di Firenze, Firenze, Italy
*Presenting author

In the satellite thermal remote sensing, the new sensors with high-spatial resolution open the door for a major thermal constraining of volcanic phenomena. Combining the high spatial resolution images with moderate resolution sensors as MODIS, with a high revisit frequency, can greatly increase monitoring capabilities.
Here we present preliminary results on the comparison between thermal data series, derived from SENTINEL-2 and MODIS, at Stromboli and Etna volcanoes in the mid 2015 - 2018 timespan. To analyse the SENTINEL-2 images, we applied an algorithm based on SWIR bands 8a-11-12 analysis, with a 20-meter spatial resolution. We compare the thermal trends and the number of pixels alerted from SENTINEL-2 with the Volcanic Radiative Power (in MW) datasets, the latter processed by the MIROVA system. The outcomes presented show interesting comparable trends between the two imagery suites, indicating how the SWIR/SENTINEL-2 signal is a clear marker of the volcanic activity, able to distinguish different magnitudes and typologies of activity. The SENTINEL-2 thermal signal turns out to be suitable to track the thermal variations of heat sources and, particularly, the high-spatial resolution allows localizing precisely the anomalies and detail morphometric features of heat sources, such as area and thermal distribution. Considering the presence of close active craters in the summit area of Stromboli and Etna, the high-spatial resolution potentiality let to decrypt which is the thermal contribution of the different vents and to understand their evolution in terms of intensity and persistence.
The promising results at Stromboli and Etna volcanoes indicate how the integration of MODIS-MIROVA and SENTINEL-2 data constitutes the first step for a future application in a multi-sensor hot spot detection system, with increased monitoring capabilities and useful for communities which relate with active volcanoes.

The Na/K solute geo-thermometer: comparison of thermodynamic database and measure in volcanic hydrothermal systems.

Pierangelo Romano*, Marcello Liotta

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Palermo, Italy
*Presenting author

Volcanic-hydrothermal systems are characterized by multiphase fluid flow processes responsible for complex chemical reactions and heat transfer from magma.
In the last decades, a growing number of works has focused on the study of thermal waters using several tools to evaluate deep temperature in geothermal systems in order to provide key information about volcanic unrest. Solute geothermometers represent a powerful tool to estimate deep water temperatures. In Giggenbach [1988], thermal-water composition is used to classify groups of water and their origin, and to prove if water-rock equilibrium (i.e the equilibrium of a thermodynamically stable mineral phase with water) is attained [Giggenbach, 1981]. At equilibrium conditions, water-rock interaction implies the simultaneous existence of dissolution, precipitation and exchange processes under given temperature, pressure and salinity conditions. If the equilibrium is attained, geo-thermometers can provide a realistic evaluation of the temperature.
In this work, we compare the equation for the Na/K geothermometer proposed in the scientific literature with existing thermodynamic database and measured Na/K ration in deep thermal water of volcanic geothermal area. Our final aim is seeking where equation/model to estimate deep water temperature in volcanic geothermal area are effective also in relation to the rock-forming mineral and secondary mineral that may characterize a specific volcanic area.

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Barbara ANGIONI
Istituto Nazionale di Geofisica e Vulcanologia

Istituto Nazionale di Geofisica e Vulcanologia
Via di Vigna Murata, 605
00143 Roma
tel. +39 06518601

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