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Workshop on

Explosive eruptions and the Mediterranean Civilizations through prehistory and history

12 | 16 September 2017, Ustica, Italy

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Editors Mariangela La Monica and Licia Corsale

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SCIENTIFIC PROGRAM

Explosive eruptions and the Mediterranean Civilizations through prehistory and history

An international workshop on the present state of knowledge on explosive eruptions in the Mediterranean area, and their impact on the environment and human civilization

EXPLOSIVE ERUPTIONS and the MEDITERRANEAN CIVILIZATIONS through PREHISTORY and HISTORY | USTICA 12 | 16 September 2017

12 SEPTEMBER | Afternoon

15:30-18:30 Arrival of participants and registration at the *Auditorium – Teatro Comunale*

Evening

21:30-22:30 Icebreaker party at *Museo Archeologico "P. Carmelo Seminara"*

22:30-23:30 Visit to the *Museo Archeologico "P. Carmelo Seminara"*

13 SEPTEMBER | Morning

09:30-10:00 Welcome from the Authorities and the Organizing Committee

10:00-10:30 Barberi F. – *Key lecture on Explosive eruptions in the Mediterranean* (Invited)

10:30-11:00 Coffee break

Chairman: Maria Luisa Carapezza

11:00-11:20 White J., Rotolo S. – *Basaltic Magmatism in the Sicily Channel*

11:20-11:40 Romano P., Andujar J., Scaillet B., Di Carlo I., Rotolo S.G. – *Phase relationships of a chemically-zoned peralkaline silicic reservoir: the example of Green Tuff eruption at Pantelleria (Italy)*

11:40-12:00 Karatson D., Gertisser R., Vereb V., Telbisz T., Quidelleur X., Nomikou P., Druitt T., Kósik S. – *Reconstructing 'Atlantis', the Late Bronze Age island of Santorini*

12:00-12:20 Zuccaro G. – *Cascading effects and cumulative* *impacts of volcanic eruptions: simulation model and decision support tool application in Santorini*

12:20-12:40 Massaro S., Costa A., Sulpizio R. – *Evolution of the magma feeding system during a Plinian eruption: the case of Pomici di Avellino eruption of Somma-Vesuvius, Italy*

12:40-13:00 Di Vito M., Acocella V., Aiello G., Barra D., Battaglia M., Del Gaudio C., de Vita S., Ricciardi G.P., Ricco C. – *Multidisciplinary approach in evaluating the historical ground movements at Campi Flegrei caldera (Italy) for the reconstruction of the magma transfer before the 1538 AD*

13:00-14:30 Lunch

Afternoon

Chairman: Sebastiano Tusa

14:40-15:00 Carapezza M., Gattuso A., Ranaldi M., Sortino F., Tarchini L. – *Hazard associated with the release of volcanic gases in the village of Vulcano Porto and at Levante Beach (Vulcano Island, Italy)*

15:00-15:20 Furlani S., Foresta Martin F. – *Headland or stack? Paleogeographic reconstruction of the coast at the Faraglioni Middle Bronze Age Village, Ustica, Sicily, Italy*

15:20-15:40 La Monica M., Foresta Martin F., Rotolo S. – *Petrographic and Spectroscopic (FT-IR) study of western Mediterranean obsidians*

15:40-16:00 Furlani S., Foresta Martin F., Antonioli F., Cavallaro D., Biolchi S. – *Coastal volcanic forms at Ustica (Sicily, Italy): present-day and MIS 5.5 Tidal notches*

16:00-16:20 Sanna L. – *Petrographic features of Tertiary volcanic products used for Neolithic human settlements in Logudoro region (Northern Sardinia, Italy)*

16:20-17:00 Coffee Break and Transfer to the Poster venue

17:00-18:30 Poster Session:

Poster Authors

- Bardeglinu I., Cioni R. & Scaillet B. – *Experimental constraints on pre-eruption conditions of the 1631 Vesuvius eruption*
- Calidonna C., Cannata C.B., De Rosa R., Donato P., Scarciglia F. – *The effects of volcanic plumes on distal environments: the example of Calabria*
- Ciulla A., Romano P., D'Oriano C., Landi P., Rotolo S., White J.C., Di Carlo I. – *A melt inclusion study Green Tuff*

eruption: volatiles, major and trace elements of a chemically zoned ignimbrite

- de Vita S., Sansivero F., Biochi M., Minin G., Gialanella C. – *The impact of the Punta Chiarito Tephra on the VIII century BC Greek settlement of Pithekoussai (Ischia, Italy): eruption dynamics and emplacement mechanism*
- Di Vito M.A., de Vita S., Rucco I., Bini M., Zanchetta G., Aurino P., Cesarano M., Ebanista C., Rosi M. – *Impact of volcaniclastic flows related to 472 and 1631 AD Vesuvius sub-Plinian eruptions: stratigraphic and geoarcheological data*
- Esposito R., Paternoster G., Trojsi G., Gialanella C., de Vita S., Di Vito M.A. – *Clays from volcanoes: the clay deposits of Ischia island as a source of raw material for the Black gloss ware production in the bay of Naples (Italy), between the 2nd and the 1st centuries B.C.*
- Figlioli A., Ferlito C., Cirrincione R. – *Etna: A striking and fascinating volcano but also a danger for the Sicilians: the example of the eruption of 122 B.C.*

Foresta Martin F., La Monica M. – *The black gold that came from the sea. A review of obsidian studies at the island of Ustica, Italy*

- Li Vigni L., Correale A., Lanzo G., Romano P., Rotolo S.G. – *A study of melt inclusions in Brown Tuffs deposits, Vulcano Island*
- Lopez M., Romano D., Foresta Martin F. and Italiano F. – *Tectonic structures and anomalous degassing of Radon gas from soil in Ustica Island (Sicily, Italy)*
- Manni M. e Coltelli M. - *The volcanic events that marked the human history of Lipari (Aeolian Islands)*
- Ortiz R., Marrero J.M., Garcia A., Llinares A., Melo V. – *Risk management issues on tourist regions with explosive volcanism: The Teide's 2004 unrest, Canary Islands*
- Petit-Breuilh Sepúlveda – *El valor de los documentos històricos en la reducciòn de los desastres: la erupciòn de 1600 en el Huaynaputina (Perù)*
- Primerano P., Vona A., Giordano G., de Vita S. – *Volume-time distribution and rheological behavior of lava flows and domes from Ischia Island (Campania, Italy)*
- Ranaldi M., Carapezza M.L., Conti E., Isaia R., Pedroli R., Sicola S., Tarchini L. – *Soil gas investigations at Campi Flegrei caldera (Italy)*
- Renzulli A., Santi P., Balassone G., di Maio G., De Bonis A., Morra V. – *Lava pebbles used in past human activities (case studies of Middle Bronze Age and Roman Period): witnesses of an old trachyte effusive activity of Mt. Somma volcano*
- Romano P., Angelone E., Palumberi M., Landi P., Rotolo S.G. – *A melt inclusion study of mafic to felsic tephra at Ustica Island, southern Tyrrhenian Sea*
- Speranza F., Hernandez-Moreno C., de Vita S., Marotta E., Sansivero F. – *Paleomagnetic dating of historical and prehistorical eruptions of Ischia (Italy): a tool to answer open chronostratigraphic questions*
- Tarchini L., Barberi F., Carapezza M.L., Gattuso A., Ranaldi M., Sortino F. – *Geochemical evidences of increasing magmatic gas input before the seismic swarm apex of the 2011-12 volcanic unrest of Santorini, Greece*

19:00-20:00 Visit to the Laboratorio Museo di Scienze della Terra Isola di Ustica

14 SEPTEMBER | Morning

09:00-12:30 Field trip: circumnavigation of Ustica island
Field Leaders: Sandro de Vita and Franco Foresta Martin

12:30-14:00 Landing and lunch

Afternoon

Chairman: Roberto Sulpizio

14:30-14:50 Foresta Martin F. – *A one million year long walk. The foundation of Laboratorio-Museo di Scienze della Terra and the valorization of the volcanological history and of the geosites at Ustica island* (Invited)

14:50-15:10 Ortiz R., Garcia A., Marrero J.M., de la Cruz-Reyna S., Carniel R., Vila J. – *Seismic and volcanic activity forecasting: Scientific advances and examples obtained in different types of active volcanoes*

15:10-15:30 Alexandrakis G., de Vita S., Di Vito M. – *Vulnerability and risk assessment based on natural and human induced indicators at Ustica (Italy)*

15:30-15:50 Furlani S., Foresta Martin F. – *Micro erosion rates on volcanic rocks at Ustica (Italy)*

15:50-16:10 Scandone R., Giacomelli L. – *The eruptions and the history of the exploitation of geothermal resources at Campi Flegrei and Ischia*

16:10-16:30 Spatafora F. – *Human settlements at Ustica since Neolithic times* (Invited)

17:00-17:30 Coffee Break

Evening

17:30-19:00 Panel discussion on hazard assessment, risk communication, emergency planning

Moderator: Franco Foresta Martin

22:30-23:30 Visit to the Centro Studi e Documentazione Isola di Ustica

15 SEPTEMBER | Morning

Chairman: Silvio Rotolo

09:00-09:30 Italiano F. – *Submarine volcanic and faulting activity in the southern Tyrrhenian Sea: Examples from study cases between Ustica Island and the Aeolian Arc and perspectives to improve our knowledge* (Invited)

09:30-09:50 Nave R. – *Risk perception for volcanic hazards on active volcanic islands: Ischia, Lipari, Stromboli, Vulcano (Italy), La Reunion (France), and San Miguel (Portugal)*

09:50-10:10 Risica G., Speranza F., Giordano G., De Astis G., Lucchi F. – *Paleomagnetic dating of the Neostromboli sequence*

10:10-10:30 Zuccaro G. – *Impact of explosive volcanic eruptions: a dynamic simulation assessment model for Vesuvius and Campi Flegrei*

10:30-10:50 Karátson D., Veres D., Wulf S., Gertisser R., Lahitte P., Dibacto-Kamwa S., Novothny Á., Magyari E., Jánosi Cs. – *Explosive eruptions and tephra dispersal from Ciomadul (Csomád) volcano, East Carpathians*

10:50-11:15 Coffee Break

11:15-18:00 Field trip on Ustica geology and packed lunch
Field Leaders: Sandro de Vita and Franco Foresta Martin

Evening

20:00 Social dinner

16 SEPTEMBER | Departure

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Contents

Preface

Since the origin of humanity volcanism and human life have been strictly linked to each other. Despite the hazards posed by volcanoes, humans have always found good reasons for settlement and development around them, mostly in temperate zones, because of high soil fertility or for the presence of ore deposits and the abundance of volcanic rocks that are good building materials.

Evidence from archaeological excavations demonstrates that volcanic and related phenomena often have strongly conditioned human life, causing environmental changes, forcing people to abandon their settlements, and preparing the conditions for later recolonization and soil exploitation during phases of quiescence.

The Mediterranean region is one of the most impressive examples of this interaction, where the development of civilization has been repeatedly boosted and hindered.

More recently, as demonstrated by the 2010 Eyjafjallajökull eruption (Iceland), the impact of even moderate-scale eruptions is amplified by the increasing vulnerability of modern society related to growing population, rising standard of living, settlement and industrialization of very exposed regions, and complex interdependencies in commerce, including transport and trade systems at a global scale.

The main goal of this workshop is to promote cultural exchange and interaction among diverse disciplines, so as to enhance our knowledge of the relationships between volcanism, environment and human communities, and exhibit and spreading the best practice of scientific culture dissemination about explosive volcanism.

Organizing and Scientific Committee

Vulnerability and risk assessment based on natural and human induced indicators at Ustica (Italy)

Alexandrakis G.[1,2], de Vita S.[1], Di Vito M.A.[1]

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[2]*Institute of Applied and Computational Mathematics, Foundation for Research and Technology - Hellas, Greece*

Geomorphological phenomena have significant repercussions on the environment, triggering changes in the natural processes that might have a severe socio-economic impact. So far, the estimation of vulnerability has been based, primarily, on the natural processes and, secondarily, on socio-economic variables, which would assist in the identification of vulnerable areas. The present investigation proposes a methodology to estimate the risk from natural hazards of the Ustica Island by introducing human-induced indicators. The different indicators form indices that are used for a holistic risk estimation for both the inland and the coastal areas of Ustica. The methodology is constructed on a GIS-based combination of socio-economic indicators and existing natural indicators, such as soil erosion, landslides and coastal vulnerability. This approach includes four sub-indices that contribute equally to the overall index. The sub-indices refer to the geomorphological characteristics that include the geomorphology of the area, the slope gradient, the slope aspect, the lithology and the drainage system density. Natural forcing indicators are related to structural stability of the geological formations, percentage of vegetation cover, soil erosivity, soil thickness. Also, the type of landslides has been considered along with land cover and the hazards related to the volcanic nature of the island. Coastal erosion indicators consider geological variables like coastal geomorphology, historical coastline changes, and regional coastal slope and marine processes like relative sea level rise, mean significant wave height, and tidal range.

The socio-economic index includes indicators, such as settlement size, cultural heritage sites, transport network and infrastructure, land use and economic activities. All variables are ranked on a 1-5 scale with the rank 5 indicating the highest vulnerability. The main difficulty for the estimation of the index lies in assessing and ranking the socio-economic indicators.

Finally, a risk assessment was estimated by using the definition of risk proposed by the European Commission, where risk is defined as “the probability of harmful consequences, or expected losses (deaths, injuries to property, livelihoods, disruption to economic activities or environment), resulting from interaction between vulnerability and exposure”. Therefore, the vulnerability of the area to a hazard is estimated as the probability of risk, with the socioeconomic sub index functioning as the exposure variable.

For the inland part the three sub-indices that are used (Geomorphological characteristic, natural factors and socioeconomic index) were analysed in a ternary diagram in order to identify the areas that each index contributes more to the final risk estimation. The same approach has been applied to the coastal area, subdividing the coastal vulnerability index into two sub-indices (a sub-index that represents the coastal characteristics and a sub-index that represents coastal forcing), in order to identify the importance of each sub index to each area.

This paper is an initial approach that will be tested and validated through field and desktop studies, using as a case study the Ustica island; an area of high cultural, naturalistic and economic value, which combines the great beauty of the landscape with the geo-volcanological interest of the outcropping rocks and the vestiges of ancient civilizations.

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Explosive volcanism in the Mediterranean area

Barberi F.

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The main types of explosive volcanic eruptions, from Strombolian to Vulcanian to Plinian, take their name from three active or quiescent Italian volcanoes: Stromboli, Vulcano and Vesuvius.

These volcanoes are located in the southern Tyrrhenian Sea, from Sicily to the Naples region, which counts also the important quiescent explosive volcano of Campi Flegrei. Another important zone of explosive volcanism in the Mediterranean area is the Aegean island arc in Greece, including Santorini volcano, the site of the so-called "Minoan" eruption and the related tsunami generating caldera collapse. These volcanoes are located in densely inhabited or touristic zones and the repetition nowadays of a high-energy explosive eruption, similar to those of the past, would produce a dramatic disaster for people, lifelines and goods. The eruptive reactivation of a quiescent volcano is preceded by precursory signs such as anomalous seismicity, ground uplift and physical-chemical changes in fumaroles and hot springs, which can be easily recognized if the volcano is well monitored. Unfortunately, however, these precursory signs can indicate at the best that a new eruption is impending, but they not provide any indication on its type and energy. This basic information, of fundamental importance for any risk analysis and for preparedness measures, is obtained so far from the eruptive history of the volcano without knowing precisely its present conditions, i.e. dimensions, depth and rheology of its magma reservoir. This represents the major limit of present volcanology and it should orient the future scientific research.

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Experimental constraints on pre-eruption conditions of the 1631 Vesuvius eruption

Bardeglinu I.[1,2], Cioni R.[3] & Scaillet B.[2]

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The knowledge of the range of possible styles of magmatic activity to be expected for a next reactivation at dormant active volcanoes as Somma-Vesuvius is a very challenging task, and a first order information in terms of volcanic hazard assessment and emergency planning. Magma composition and its general physical conditions strongly control the style of volcanic activity, directly influencing magma rheology, volatile content and style of degassing. Experimental petrology conducted on the products of past activity has been used as a tool for revealing the conditions of pre-eruptive magma crystallization, defining the general stability fields of the different mineralogical phases under different conditions of pressure P, temperature T and volatile fugacity (X) in the coexisting fluid phase. Evidence exists that after the famous AD 79 Pompeii eruption, a major change in the shallow magmatic system occurred, marked by the shallowing of the magma reservoir feeding the main eruptions. However, while the products of the AD 472 eruption have been the object of in depth studies aimed at defining PTX magma conditions, the products of the 1631 event are not still well studied in this respect. We present here data on the mineral phase stability for this very important eruption, aimed at fixing the expected range of magma composition and physical properties for this eruptive scenario. About 30 runs on natural tephritic phonolite were performed on an Internally Heated Pressure Vessel under controlled P, T X_{H2O} and redox conditions. Phases identified include quenched glass (Gl), clinopyroxene (Cpx), leucite (Lc), biotite (Bt), plagioclase (Pl), and fluid (Fl), the latter as voids of 10-100 microns sizes evenly dispersed accross the charge. Mineral sizes vary from a few tens of microns (Lc, Bt) down to a few microns (Cpx). In order to constrain pre-eruptive conditions, composition of glass and mineral phases was checked against data collected on natural samples. In particular, the occurrence of Bt in natural samples implies pre-eruptive T below 1000 °C. Experimental results also allowed tracing thermometric relationships based on Gl composition, which implement and improve those already existing.

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The effects of volcanic plumes on distal environments: the example of Calabria

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Both positive and negative effects of plumes produced during the explosive eruption of southern Italy active volcanoes on the Calabria territory are analysed and discussed.

Unlike other natural disasters such as floods, landslides, wild fires and earthquakes, volcanoes can have some positive effects, even though they can be very disastrous.

It is known that ash discharged into the atmosphere can have several negative impacts, such as climate modifications, damages to agriculture, water, soil and air pollution also in areas far from the volcanoes.

During the eruptions of M.te Etna the eruptive plume rich in gas and ash is occasionally dispersed northward contributing to influence air quality also in Calabria. As an example, the 16-17th November 2013 paroxysmal eruption produced a remarkable peak in PM10 concentration (71.6 μg m^{-3}) at Lamezia Terme, corresponding to tenfold increase in respect to the typical PM10 levels observed at this measurement site. SEM observations revealed the presence of gypsum and other sulphur minerals affecting the aerosol at Lamezia Terme.

Often during Etna eruptions (e.g. 23/11/2013) a great amount of ash covers the southern sector of Calabria, interacting with soils and groundwaters. Leaching experiments on the fine (<2mm) particulate from Stromboli and Etna indicate that freshly deposited volcanic ashes can release great amounts of potentially harmful compounds because adsorbed acidic gases and the salts formed by their reaction with glass are readily soluble. Experiments carried out using strongly acidic (pH=2), weakly acidic (pH=5) and alkaline (pH=9) solutions, at varying contact times indicate that most of dissolution takes place within the first 5000 minutes and that the highest concentration of leachates are obtained in acid condition (pH=2). After 21000 minutes, the solution reaches the steady state, suggesting that leaching may be related to the sublimates; only later the appearance of new peaks of elements (Ca, Mg e SO_4) suggests that dissolution may affect also the glassy fraction. Therefore, even volcanic ashes, which have already interacted with rainwater, maintain a lower but significant potential to release compounds that could be harmful to the environment.

However, ash deposition may also have positive effects on soil fertility. In Calabria several soils developed on mixtures of distal volcanic ash from southern Italy volcanoes and local non-volcanic parent materials, including both proper Andosols and other soil types. Very often these soils are particularly fertile, because of a high nutrient availability supplied by the fast weathering of glass components, coupled with a high water retention capacity.

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Hazard associated with the release of volcanic gases in the village of Vulcano Porto and at Levante Beach (Vulcano Island, Italy)

Carapezza M.L.[1], Gattuso A.[3], Ranaldi M.[1,2], Sortino F.[1], Tarchini L.[1,2]

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Vulcano Island along with Stromboli, Lipari and Panarea is among the active volcanic islands of the Aeolian archipelago. Since its most recent eruption in 1888-1890, La Fossa cone remained quiescent and characterized by an intense fumarolic activity. The main fumarolic fields are located at La Fossa crater and Levante Beach. La Fossa cone, including its flanks and a wide area at its base, is characterized also by an high diffuse, soil CO_2 degassing. After the 1888-90 eruption, episodic "crises" occurred at La Fossa cone with increase of temperature, gas output and concentration of magmatic components in the fumaroles. The first of these crises occurred in 1913-23 and Siccardi reported his careful observations on the crater area fumaroles, considering that a new eruption was possible. The island was almost inhabited at that time, but since 1960 Vulcano developed its touristic vocation and Vulcano Porto village, located at La Fossa cone base, grew up rapidly. Unfortunately, this urbanization included also zones affected by hazardous diffuse degassing. The first negative effects emerged during the 1988-1993 crisis, when the accumulation of CO_2 in morphological depressions within Vulcano Porto provoked the death of two children and of many small animals at the base of La Fossa cone. Since 1898 systematic soil CO_2 flux investigations have been carried out at the base of cone, including Vulcano Porto area to monitor the gas output. The most recent crisis occurred in 2004-2006 and in 2005 a detailed study of the endogenous soil gas emissions was carried out at Vulcano Porto to assess the gas hazard by investigating the outdoor and indoor air concentrations of CO_2 and H_2S. Results evidenced the presence of anomalous CO_2 concentrations, exceedings the hazardous thresholds, in basement and ground floor of many houses, as well as in depressed areas. Also Levante Beach and the sea in front of it are affected by an intense H_2S and CO_2 degassing. Here, the total soil CO_2 flux has been assessed in 4-6 t/day (from 0.19km^2) in intercrisis period, whereas during the 2004-2006 crisis it reached a twice higher value (14.2t/day). In April 2015, a child lost his senses while playing at Levante Beach; he was rescued to the hospital and doctors attributed to CO_2 his malaise. In 2015-2016 summers we performed geochemical surveys on the Levante Beach sector (onshore and offshore) to assess the CO_2 and H_2S release to the atmosphere. In the mud pool area, CO_2 and H_2S air concentrations were continuously measured for a week. The [CO_2] was frequently higher than in unpolluted air. [H_2S] displayed high values (max 43 ppm), frequently exceeding TWA (10ppm) and STEL (15ppm) thresholds. Offshore, gas concentration in air at sea level over the submarine fumaroles displayed extremely high and dangerous H_2S (max 1000ppm) and CO_2 (8.6vol%) values. Results confirm the occurrence of high air gas concentrations, particularly of H_2S, near the onshore and offshore fumaroles and at the mud pool, marking the persistence of a serious gas hazard for people in the highly frequented touristic site of Vulcano Porto, even in no-crisis periods and hazard would obviously increase during unrest.

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A melt inclusion study Green Tuff eruption: volatiles, major and trace elements of a chemically zoned ignimbrite

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The Green Tuff Plinian eruption (45 ka) on the island of Pantelleria (Sicily) is the most energetic eruption of Pantelleria. Among the numerous ignimbrites emplaced on the island, the Green Tuff (≤ 3km^3 D.R.E) is the only one that shows compositional zoning, passing from a crystal-poor pantellerite at the bottom and intermediate levels to a crystal-rich trachyte at the top. Several studies have paid attention to the chemical composition and volatile contents of melt inclusions (MIs) trapped in phenocrysts from the pantelleritic members, but less attention was given to the trachytic uppermost one. Here, we present the results of a detailed study performed on melt inclusions trapped in crystals present in the products from the bottom, intermediate and top members of the Green Tuff. MIs trapped in alkali feldspar (pantelleritic members) and clinopyroxene (trachytic member) were analyzed by electron microprobe, laser ablation ICP-MS and infrared spectroscopy (FT-IR). Results indicate that MIs from the bottom and intermediate members have a pantelleritic composition, with SiO_2=69-72 wt% and peralkalinity index (P.I.)= 2.05-2.11, while those from the top member are trachytes with SiO_2= 62-66 wt% and PI= 1.15-1-2.7.Trace elements contents in MIs show a progressive depletion in LREE, Rb, Y, Zr, Nb, Th, U from the pantelleritic to the trachytic members. Ba and Sr peak in the trachytic top member, which is also characterized by a positive europium anomaly (Eu/Eu*=1.27). A strong negative anomaly (Eu/Eu*=0.46) is observed from the MIs of the pantelleritic member. As regards to the volatile content, a surprisingly lower H_2O content is found in the MIs from the trachytic member (H_2O ≤1.1wt%) with respect to the concentrations reported by Lanzo et al. (2013) for the Green Tuff pantelleritic basal fall-out (≤ 4.2 wt%). CO_2 content always below the detection limit (ie. <50 ppm). Considering the composition of the two end-members, mass balance calculations, including both the major and trace elements contents, support the origin of the pantelleritic liquids from a trachytic parental melt via 70% of crystal fractionation of alkali feldspar, clinopyroxene, olivine and aenigmatite.

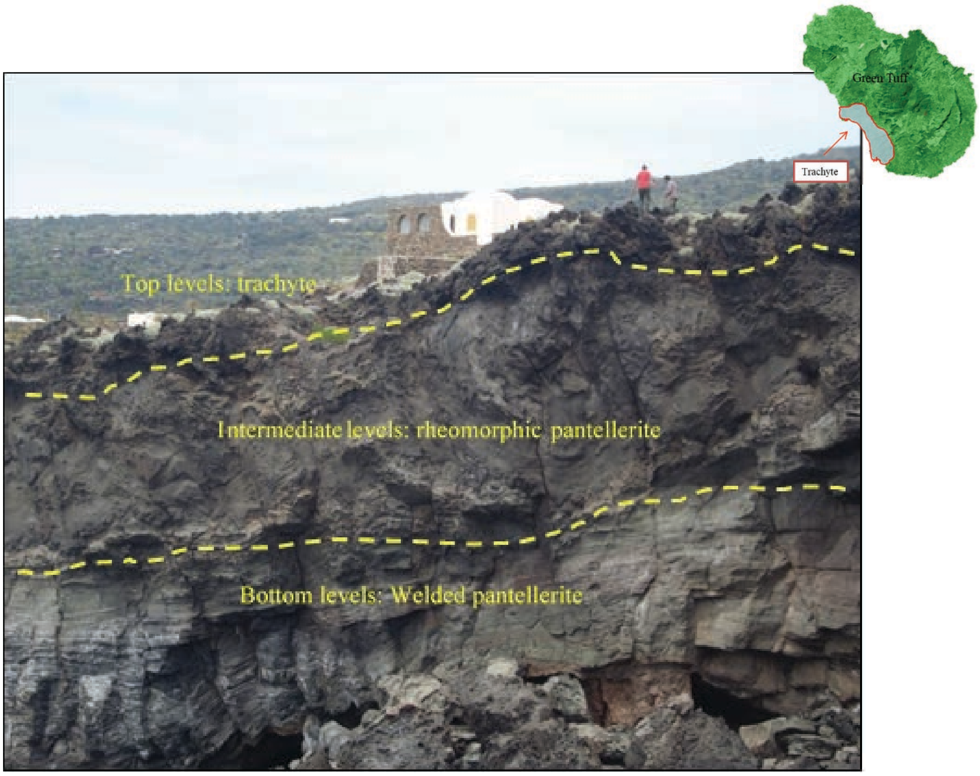

Figure 1. The image shows the transition from pantellerite at the bottom and intermediate levels to a trachyte at the top of Green Tuff.

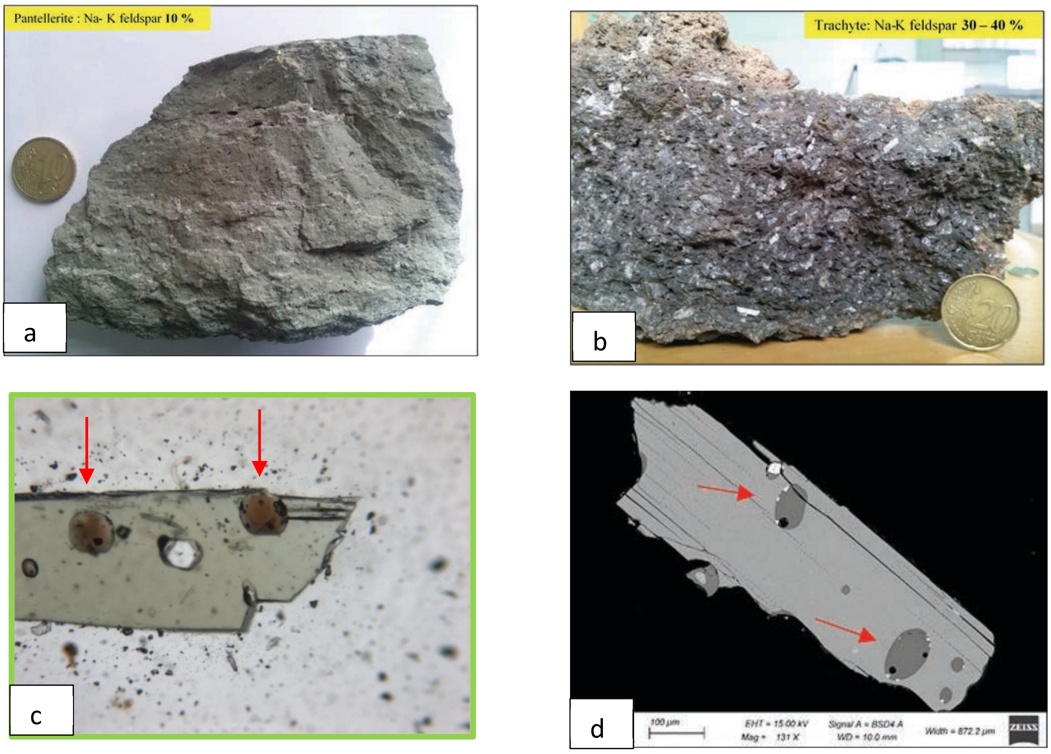

Figure 2. a) Crystal-poor pantellerite b) Crystal-rich trachyte c) Melt inclusion in clinopyroxene (trachytic member), Visual observation (Optical microscope) d) Melt inclusion in clinopyroxene (trachytic member), Visual observation (EMP).

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The impact of the Punta Chiarito Tephra on the VIII century BC Greek settlement of Pithekoussai (Ischia, Italy): eruption dynamics and emplacement mechanism

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The Punta Chiarito Tephra (ChT) is a pyroclastic deposit belonging to the last 10 ky of volcanic activity of Ischia resurgent caldera. It has has been archeologically dated at the end of the 8th century BC as it buried a human settlement of this age. Although almost all the volcanic vents of the past 5 ky are located in the lowland bordering eastward the resurgent block of the caldera, the ChT is the sole deposit exposed in the western sector of the island, covering an area of at least 5 km^2.

The ChT has been subdivided in Eruption units and sub-units according to the observed sedimentological features. Clasts morphology, degree of vesiculation and sedimentary structures, analyzed both in the field and laboratory through grainsize and SEM analyses, allowed the reconstruction of the eruption dynamics, type of fragmentation, transport mechanisms and depositional processes. The variations of geometrical and sedimentological characteristics (shape, thickness, grainsize, sedimentary structures) of each unit, together with direction of provenance of ballistic clasts, were used to constrain the position of the eruption vent, presently buried under landslides.

The ChT sequence was generated by a succession of magmatic and phreatomagmatic explosions that extruded a homogeneous alkali-trachytic, well-vesicular and porphiritic magma. The eruption began with a phreatomagmatic phase, which generated the basal surge of Member A. A violent strombolian-to-subplinian eruption column formed soon after and produced the fallout deposit of Member B. In the following water entered the conduit leading to a new phreatomagmatic phase, with the emplacement of the dilute pyroclastic density currents of Members C to E. The eruption ended with the formation of a pulsanting sub-plinian magmatic column generating the fallout deposit of Member F. Lithic clasts and SEM investigations indicate a progressive increase of water-magma interaction during the course of deposition of member C and its decrease from member D to F. Sr-isotopic ratio for crystals and whole-rocks indicates that the magma batch was isotopically homogeneous and deviated its composition during the eruption, towards more radiogenic values in response to magma-water interaction.

The eruption had a significant impact on a farm, located on top of the Punta Chiarito promontory, burying a house with elliptical base and the surrounding cultivated fields. Traces of cereals growing, mollusks catching, and stock-raising show that the Punta Chiarito settlement was part of a self-supporting village included in the *chora* of the Greek colony of Pithekoussai. This was founded around 770 BC and represents the first Greek colony in southern Italy. After the eruption the house was restored and utilized again through the late 7th and the early 6th century BC, when it was finally buried by the products of a giant landslide, detached from the Mt. Epomeo south-western slope.

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Multidisciplinary approach in evaluating the historical ground movements at Campi Flegrei caldera (Italy) for the reconstruction of the magma transfer before the 1538 AD eruption

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Defining and understanding the shallow transfer of magma at volcanoes is crucial to forecast eruptions, possibly the ultimate goal of volcanology. This is particularly challenging at felsic calderas experiencing unrest, which typically includes significant changes in seismicity, deformation and degassing rates. Caldera unrest is particularly frequent, affects wide areas and often does not culminate in an eruption. Moreover its evidence is usually complicated by the presence of a hydrothermal system. As a result, forecasting any eruption and vent-opening sites within a caldera is very difficult.

The Campi Flegrei caldera (CFc), in the densely inhabited area of Naples (Italy), is commonly considered one of the most dangerous active volcanic systems. CFc is a ~12 km wide depression hosting two nested calderas formed during the eruptions of the Campanian Ignimbrite (~39 ka) and the Neapolitan Yellow Tuff (~15 ka). In the last ~5 ka, resurgence, with uplift >60 m close to the central part of the caldera, was accompanied by volcanism between ~4.8 and ~3.8 ka. After ~3 ka of quiescence, increasing seismicity and uplift preceded the last eruption at Monte Nuovo in 1538 for several decades. The most recent activity culminated in four unrest episodes between 1950-1952, 1969-1972, 1982-1984 and 2005-Present, with a cumulative uplift at Pozzuoli of ~4.5 m; the present unrest episode has been interpreted as being magma-driven. These unrest episodes are considered the most evident expression of a longer-term (centuries or more) restless activity. The post-1980 deformation largely results from a magmatic oblate or sill-like source at ~4 km depth below Pozzuoli.

Despite the restless activity of CFc, the recent unrest episodes did not culminate in eruption, so that any possibility to define the pre-eruptive shallow transfer of magma remains elusive. Indeed, this definition is a crucial step in order to identify and understand pre-eruptive processes, and thus to make any forecast. To fill this gap, we focused on the last eruption of 1538, reconstructing its pre-eruptive deformation pattern. For this, we exploited the unique historical, archaeological, geological and long-term geodetic record of the caldera to carefully determine the height variations (and related errors) of 20 selected sites along its coastline. The integration of this large dataset permitted the first reconstruction of pre-eruptive short- and long-term ground deformation of the CFc and to model the magma transfer before the eruption. Our data suggest a progressive magma accumulation from ~1251 to 1536 in a 4.6±0.9 km deep source below the caldera centre, and its transfer, between 1536 and 1538, to a 3.8±0.6 km deep magmatic source ~4 km NW of the caldera centre, below Monte Nuovo; this peripheral source fed the eruption through a shallower source, 0.4±0.3 km deep. This reconstruction corroborates the existence of a stationary oblate source, below the caldera centre, that was feeding lateral eruptions for the last ~5 ka, and suggests: repeated emplacement of magma through intrusions below the caldera centre; occasional lateral transfer of magma feeding noncentral eruptions within the caldera. Comparison with historical unrest at calderas worldwide suggests that this behavior is common.

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Impact of volcaniclastic flows related to 472 and 1631 AD Vesuvius sub-Plinian eruptions: stratigraphic and geoarcheological data

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There is a growing number of evidences in the surrounding plain of Somma-Vesuvius volcano that indicate that along with primary volcanic processes (i.e. fallout, pyroclastic density currents) the syn-eruptive and post-eruptive volcaniclastic remobilization has severely impacted the ancient civilizations, which flourished in the area. This represents an important starting point for understanding the future hazard related to a potential (and not remote) renewal of volcanic activity of the Campanian volcanoes. We present geoarcheological and stratigraphic data obtained from the analysis of more than 250 sections in the Campanian plain showing the widespread impact of volcaniclastic debris flows and floods originated from the rapid remobilization of the products of the AD 472 and 1631 eruptions of Somma-Vesuvius, both on the environment and on the human landscape. This eruptions were the two largest historical events of Somma Vesuvius following the Plinian Pompei eruption. This events largely impacted the northern and eastern territory surrounding the volcano with deposition of a complex sequence of pyroclastic-fallout and -current deposits. These sequences were variably affected by syn- and post-eruptive mobilization both along the Somma-Vesuvius slopes and the Apennine valleys with the emplacement of thick mud- and debris-flows which strongly modified the preexisting paleogeography of the Plain with irretrievable damages to the agricultural and urban landscape.

The multidisciplinary approach to the study of the sequences permitted to reconstruct the palaeoenvironment before the two studied eruptions and the timing of the emplacement of both pyroclastic and volcanoclastic deposits. The area affected by syn-eruptive debris flows was larger than that directly covered by both pyroclastic fallout and flows. They have been observed in areas of the Campanian Plain surrounding Vesuvius up to distances of some kilometers from slopes of both Vesuvius and Apennine. Our analysis has revealed that the two eruptions generated a diffuse hydrogeological destabilization of a large territory surrounding the volcano, also not directly affected by the eruptions, including the area presently occupied by the city of Napoli.

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Clays from volcanoes: the clay deposits of Ischia island as a source of raw material for the Black gloss ware production in the bay of Naples (Italy), between the 2nd and the 1st centuries B.C.

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The archaeological superintendence activity has helped to enrich the knowledge of the ancient Roman city of *Puteoli*, in particular the archaeological surveys carried out in the nineties of the last century, in the context of a broad project of re-qualification and enhancement of the Rione Terra, the promontory on which the colony was allocated, made it possible to acquire important information about the Phlegraean city in the late-republican age. The excavations have highlighted fragments of black gloss ware, used as part of the filling of a well.

The analysis and reconfiguration of the fragmentary preserved pottery allowed to identify the material as a kiln waste and consequently to document a local black gloss ware production, chronologically framed between the first half of the 2nd century B.C. and the first half of the I century. B.C.; the forms produced are found in the main Mediterranean sites and wrecks.

This production is part of the *Campana A* black gloss ware production system, highlighting the characteristics of a complex production system organized on several ateliers located in the Gulf of Naples.

Archaeological studies have been associated with archeometric (mineralogical and chemical-physical) analysis of contemporary productions from *Puteoli*, *Neapolis* and Ischia to determine the specific characteristics of the phlegrean production; in addition, samples of clay from Ischia Island, known for its deposits, have been analyzed as, to date, these are the only known clay deposits in the Gulf of Naples, which are close to the Phlegrean city. The results of the archeometric analysis, along with the determination the characteristics of the *Puteolis'* production, have documented the presence of "siliceous" and "calcareous" types of clay in Ischia. This data is of great importance since so far in archaeological studies it has always been considered that the Ischia clay was solely of limestone and that the siliceous clays, used for the black gloss ware of Naples, came from the Neapolitan area, although there have never been any records of such clay banks in the same territory. Alternatively, it was also believed that Neapolitan production was produced with a mixture of clay and volcanic ash.

From this study it emerges that the siliceous clays of Ischia are compatible for their elemental composition with the analyzed ceramic specimens of the Naples workshop, thus providing new useful data for determining the supply of raw materials in the production of *Campana A* black gloss ware, which is still being debated today.

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Etna: A Striking and fascinating Volcano but also a danger for the Sicilians: the example of the eruption of 122 B.C.

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Basalt Plinian eruptions are rare and poorly known volcanic phenomena. Etna is an active basaltic volcano, the activity of which is dominated by effusive eruptions that don't represent a continuous threat to a large populated area surrounding the volcano. In this work we describe a Plinian eruption of products basaltic composition that occurred in 122 B.C. and the influence of this event on the population. This eruption is one of the most significant and important for the study of the Quaternary record. This type of volcanic activity is very laborious to get: only in four parts of the world has occurred, including Etna.

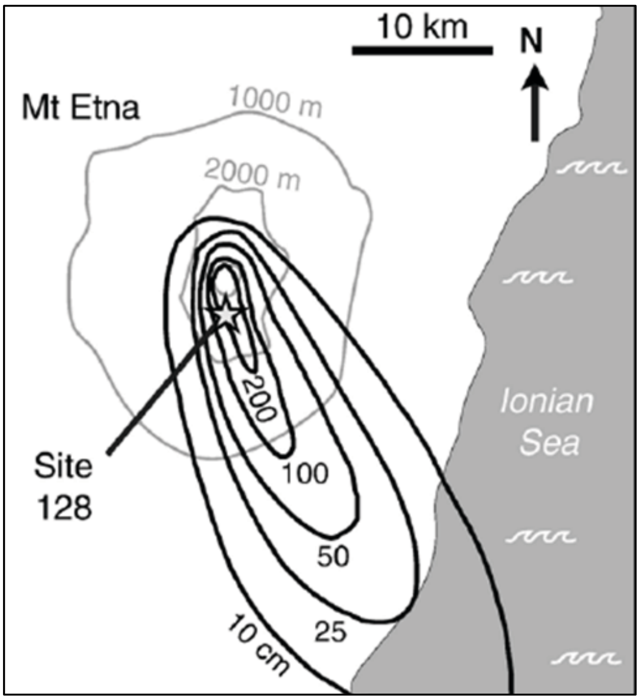

Figure 1. Etna eruption- pyroclastic expansion.

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A one million year long walk.
The foundation of Laboratorio-Museo di Scienze della Terra and the valorization of the volcanological history and of the geosites at Ustica island

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One of the most beautiful historic buildings on the Island of Ustica is the fortress built by the Bourbons in the 1700s on the remains of a Roman-Hellenistic settlement. It is located in a panoramic and symbolic place of the island: the Falconiera, which is a tuff cone of a volcano that was active about 130,000 years ago. This is the scenery where, on May 2015 the activities of the Laboratorio Museo di Scienze della Terra Isola di Ustica, in short LABMUST (Laboratory-Museum of Earth Sciences of Ustica Island), officially started. It's a cultural institution established by a Memorandum of Understanding between the City of Ustica and the Istituto Nazionale di Geofisica e Vulcanologia, INGV (National Institute of Geophysics and Volcanology).

Figure 1. Aereal view. Laboratorio Museo di Scienze della Terra Isola di Ustica.

LABMUST consists of two historical buildings included in the tuffs of the crater, both restored with funding from the Regione Siciliana. The first room houses the permanent exhibition "Ustica before Mankind". It is composed by 20 posters which illustrates the geo-volcanological history of Ustica, which started about one million years ago, when the island began to grow as an undersea volcanic mountain, on the bottom of the Tyrrhenian Southern Sea. The texts of the posters are written in a language scientifically rigorous but comprehensible to everyone. The exhibit contains also a series of itineraries useful to track the spectacular geological and volcanological formations.

Figure 2. The exhibit. Laboratorio Museo di Scienze della Terra Isola di Ustica.

A series of horizontal windows shows samples of the typical eruptive products from the island and some examples of fossils present in the sediments of its marine terraces. Alongside the permanent exhibition, there are some instruments to introduce students and visitors to the main themes of the Earth Sciences. The second room of the museum is intended as the teaching laboratory, the archive and the management.

"Museum-Laboratory" sums up the vocation that we mean to give it. The museum, with its exhibition area, as well as its didactic and informative content, shows the natural history of the island, compelling and surprising. It is a story easily understandable for ordinary visitors, but it is particularly useful to the hundreds of foreign students who often are on a school trip in the island. Particularly addressed to the latter ones, is a series of interactive exhibits we are preparing, where they can learn by experimenting and exploring.

The definition of Laboratory-Museum has also another meaning. The new institution has become a point of scientific support for the undergraduates who come to Ustica to develop their thesis on the natural features of the island. Still, the LABMUST itself has begun a research in the broad field of Earth Sciences, attracting geologists and volcanologists from all over Italy, with the aim of promoting the many unique aspects of the island.

The island of Ustica, considered ‘a paradise for divers’ by sea lovers, has an important record related to its geological formation: it is the only ‘anorogenic’ volcano emerged in the South Tyrrhenian Sea. That is to say that its magma doesn’t come from the sinking (or subduction) and the fusion of a portion of the Earth’s plate, as the nearby Aeolian Islands did. The magmas of Ustica, instead, were fed by a magma plume ascended directly from the depths of the Earth’s mantle, which followed the opening of an extensional fault on the bottom of the Tyrrhenian Sea. From the magmatological point of view, this specific nature makes the island more similar to the Etna or Hawaii rather than to the nearby Aeolian Islands, arousing the researchers’ interest.

Following a request of the LABMUST, the Regione Siciliana included some geosites of Ustica, such as Faglia dell’Arso, Monte Guardia dei Turchi and Tyrrhenian fossiliferous beach of Falconiera, in the official list of most important national geological formations (Gurs, 2016).

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The black gold that came from the sea.
A review of obsidian studies at the island of Ustica, Italy

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For more than five millennia, since Neolithic (6th millennium BC) to the Middle Bronze Age (1th millennium BC), Ustica, a tiny and solitary island 70 km north of Palermo, imported obsidian rocks from some distant sources of the peri-Tyrrhenian area. During prehistory, before the rise of metals era, the black volcanic glass was the privileged raw material used to obtain sharp and needful cutting tools or weapons, as knifes, scrapers, arrows and spearheads. Due to its usefulness, someone named obsidian the "Black Gold" of the prehistory. The import/export of obsidian feeded economical and cultural exchanges. Now, for us, the sourcing of obsidian archaeological find with geochemical and petrographic methods is essential to reconstruct the ancient routes and the relationship between ancient and distant peoples (e.g., Cann and Renfrew, 1964; Francaviglia, 1984; Francaviglia and Piperno, 1987; Bigazzi et al., 1993; Williams-Thorpe, 1995; Acquafredda et al., 1999; Tykot, 1996; Le Bourdonnec et al., 2010).

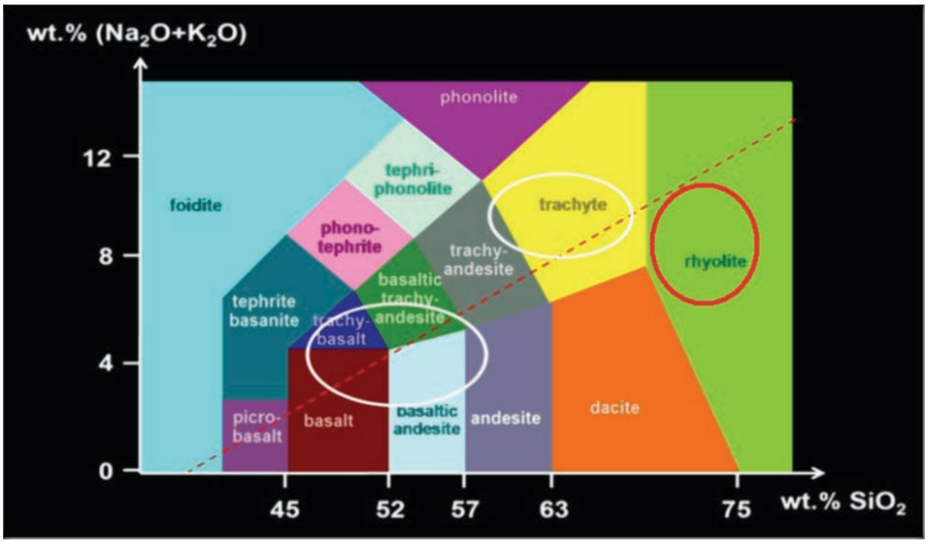

Figure 1. Total Alkali vs Silica diagram. White ellipses: composition of Ustica volcanic rocks. Red ellipse, composition of obsidian archaeological fragment collected in Ustica.

Ustica's volcanism has not formed obsidian rocks (Fig. 1), therefore we must conclude that the obsidian flakes collectible in Ustica's soil (Fig. 2) were imported from foreign sources, (Foresta Martin, 2014; Foresta Martin et al., 2016 a,b).

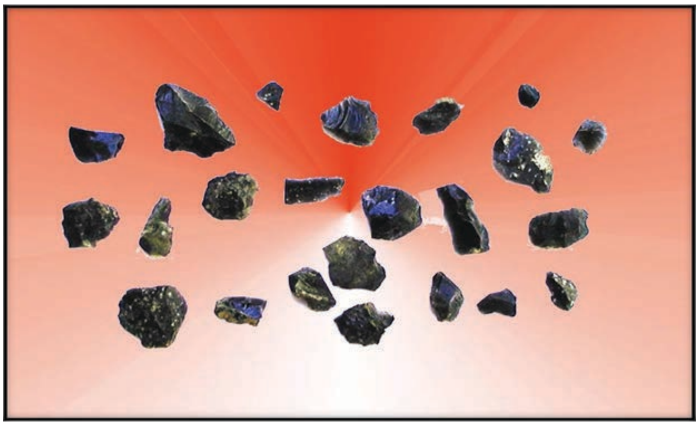

Figure 2. Obsidian fragments collected in Ustica: most of them are waste resulting from processing of big nuclei of this volcanic glass.

The obsidian distribution on the lands of Ustica isn't exclusively correlated with the existence of well known archaeological sites discovered in that island. Indeed concentrations of obsidian fragments can be found in the area of the Eneolitic settlement located in the *Piano dei Cardoni* south-est district; and in the well preserved Middle Bronze Age village named *Faraglioni*, located in the northern coast of the *Tramontana* district (Fig.3). In these locations, especially after plowing or after heavy rains, it is possible to pick up on the farmland surface something like 10-20 obsidian fragments per hour. But the soil is rich of obsidian also in some areas hundreds of meters away from the well known archaeological settlements. For example a plenty of obsidian flakes is scattered in *Tramontana Sopravia*, 500-800 m south to the *Faraglioni* village, an area which extends to the slopes of *Monte Guardia dei Turchi* hill (Fig. 3). The dispersion of obsidian in the wide district of *Tramontana* could be due to the existence of other small settlements outside the walls of the *Faraglioni* village. In particular, the large number of obsidian processing waste collectible in *Tramontana Sopravia* could be explained with the existence of an obsidian workshop in that area.

Figure 3. Main archaeological settlement at Ustica island. 1) Spalmatore, Neolithic. 2) Piano dei Cardoni, Aeneolithic. 3) Culunnella, Ancient Bronze. 4) Faraglioni Village, Middle Bronze. 5) Omo Morto, Middle Bronze.

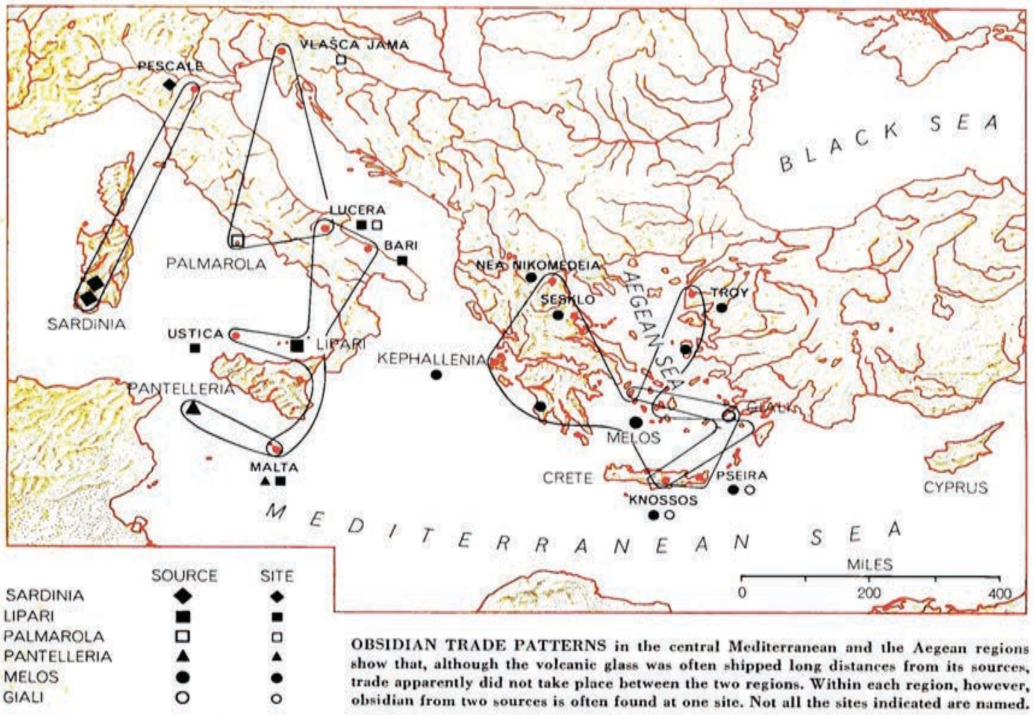

Figure 4. According to Dixon et al. (1968) Ustica imported obsidian exclusively from Lipari. But subsequent research highlited not negligible imports from Pantelleria and occasionally from Palmarola.

For a long time researches have believed that the obsidian fragments found in Ustica were all imported from the neighbouring island of Lipari. This conviction is well represented by a map (Fig. 4) that accompanied an historical article by J. Dixon, E. Cann and C. Renfrew published on Scientific American (1968), in which the authors summarized their pioneering research on the characterization of obsidian through the analysis of trace elements.

In the last few years, extensive investigation on the origin of the Ustica archaeological obsidian, promoted by the Centro Studi e Documentazione Isola di Ustica and by the Laboratorio Museo di Scienze della Terra Isola di Ustica, has led to the discovery that Ustica, while achieving most of the prehistoric imports of volcanic glasses from Lipari, made also systematic procurements from Pantelleria and, occasionally, from other distant sources (Tykot, 1995; Foresta Martin, 2014; Foresta Martin et al., 2016a,b).

Geochemical characterization on hundredths of obsidian samples, show that the use of this material in the various archaeological sites of the island persisted from the Neolithic to Middle Bronze Age, without the decline that occured in other contemporary settlements of Sicily (Tykot and Foresta Martin, 2016). Still, the analyses carried out on a large number of Ustica's obsidians show sporadic contacts with Central Italy - notably the island of Palmarola, Latium (Foresta Martin et al., 2016 a,b), in line with previous finding of a few ceramic sherds in the *Faraglioni Village* (Spatafora and Mannino, 2008).

In 2016 a group of obsidians from Ustica was entrusted to prof. S.G. Rotolo of the Palermo University (DiSTeM) for petrographic analyses carried out as a part of Dr. Mariangela La Monica's master degree thesis. The main topic of this study was the measurement, through the FT-IR spectrometry, of the amount of H_2O present in the obsidian samples that have worked edges, with the aim of applying the hydration method to calculate their absolute age. The work is in progress, but some preliminary results show the compatibility of Neolithic age for the examined obsidian sample (La Monica, 2016).

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Micro erosion rates on volcanic rocks at Ustica (Italy)

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Micro erosion meters (MEMs), following High and Hanna (1970), and traversing micro erosion meters (TMEMs), following Trudgill et al. (1981), allow to evaluate the rock lowering rates. They have been widely used on carbonate rocks in different environments, such as coasts, caves, buildings, but rarely on volcanics. We discuss preliminary data collected to from May 2016 to June 2017 in the island of Ustica, which is composed of Middle Pleistocene to Late Pleistocene volcanic rocks. The island is 8.6 km^2 and the maximum elevation is 248 m a.s.l.

The installation of micro erosion meter stations and data organization were carried out following the method suggested by Furlani et al. (2009) for the Trieste karst area.

We placed 12 stations on volcanic rocks in 7 sites on the island of Ustica to measure the lowering rates on such rocks, raging from 20 to 200 m a.s.l. Three samples were collected around the island and located at the site of Capo Falconiera, at 150 m a.s.l. The studied rocks are compact lavas and tuffs of basalt or tracky-basalt composition.

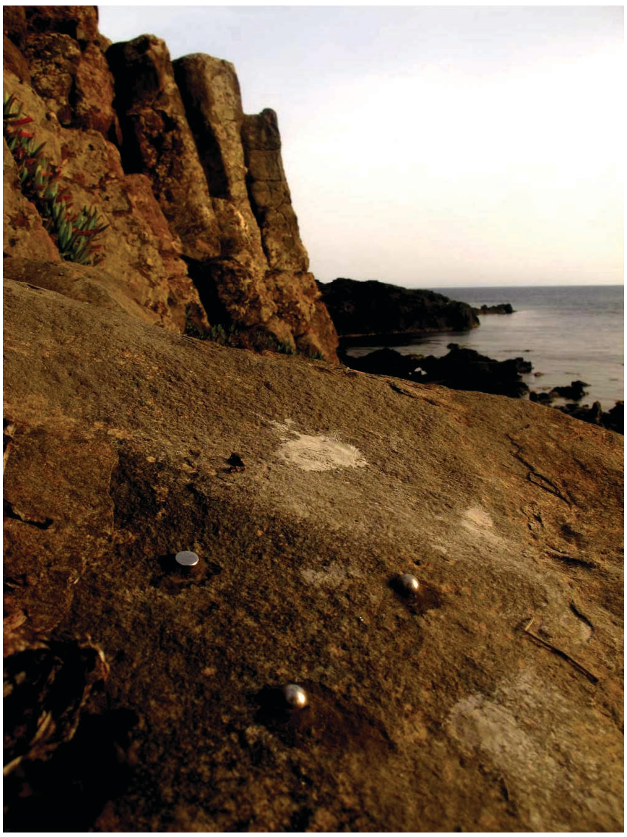

Figure 1. A micro erosion meter station at Ustica (Sicily, Italy).

The analysis of the first year measures highlighted mean lowering rates ranging from 0.001 mm/a to 0.025 mm/a. All the iron nails used in the project are oxidized after one year of measurements, suggesting to use titanium nails also for highest stations, however affected by spray weathering.

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Headland or stack? Paleogeographic reconstruction of the coast at the Faraglioni Middle Bronze Age Village, Ustica, Sicily, Italy

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Coastal archaeological sites in the Mediterranean sea often allow to reconstruct the relative sea level changes (e.g. Antonioli et al., 2007), or to piece together the paleogeography of a site (e.g. Mourtzas and Kolaiti, 2013). New bathymetric measures, together with geoarchaeological considerations, aim to reconstruct the changes of the coastline and the consequent modifications of the coastal viability of the *Faraglioni*, it. stack, *Middle Bronze Age Village* at Ustica island, 60 km north of Palermo.

The evolution of stacks, and sea arches, can be very dramatic, leading to their complete disappearance, as recently happened to the natural monument, called *Azur Window*, in Gozo. The reconstruction of their evolution can be very difficult, or impossible, just because of sudden and unpredictable changes, followed by the complete removal of the original materials. The presence of a well-preserved archaeological site close to the stack allows to suggest some landmarks in the evolution of the coastline with good precision.

The *Faraglioni Village* is considered one of the best preserved Middle Bronze Age site of the Mediterranean area (Counts and Tucks, 2009), but many doubts concern its border toward the sea, because of the local geomorphological setting. The coast is formed by 20 m-high sea cliffs, which are often subject to collapses. A small terrace develops at the cliff toe (Fig. 1). It is locally covered by a beach with pebbles and cobbles (Figg.1, 2).

Regarding the history of the site, coastal activities were reported in the island: a tiny cove, which served as harbor for small boats, is located some hundreds meters to the west. The site was also interested by long-distance contacts, as attested by imports of ceramics and obsidians (Ross Holloway and Lukesh, 1995, 2001; Spatafora and Mannino, 2008; Foresta Martin et al, 2016).

Around 3250-3200 BP the inhabitants suddenly abandoned the site, leaving all their belongings. This sudden flight is related to two hypotheses: a hostile invasion from the sea, or a natural disaster that induced the population to find a safer place (Spatafora and Mannino, 2008; Spatafora, 2009).

The main stack in front of the archaeological village is named *Colombaio*. It is 8 m wide at the top and it lies about 80 m from the shore. The cliffs at the stacks and the mainland are cut in columnar basalts, while there are many submerged or slightly emerged rocks in the canal between the stack and the mainland.

Since archaeological remains have been found on the top of the stack, archaeologists suppose that there where a connection with the mainland. Literature suggests that most probably there was a natural bridge between the stack and the coast; and that it collapsed as a result of a natural catastrophic event, such as an earthquake (e.g. Spatafora and Mannino, 2008).

We suggest that it is not necessary to hypothesize the occurrence of a bridge, both natural or human-made, because during the Middle Bronze Age, about 3400-3200 BP, the sea level was lower than today's and the stack was connected to the mainland through a headland.

The maximum depth measured in the channel separating the stack from the mainland is -2 m msl. During the Middle Bronze Age, the sea level was 3 m lower than today (Lambeck et al., 2011). A small path of rock, emerging above the sea level, connected the foot of the sea cliff with the stack. The access to the stack was therefore possible also without a human-made bridge, or the presence of a sea arch.

Figure 1. The Faraglioni stack at Ustica (Sicily, Italy).

Figure 2. Aereal view of the Faraglioni stack.

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Coastal Volcanic forms at Ustica (Sicily, Italy): Present-day and MIS 5.5 tidal notches

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The Mediterranean Sea is bordered by about 23.000 km of rocky coasts (Furlani et al., 2014a). Most of them show scenic coastal landforms, such as sea caves, sea stacks, tidal notches, etc. A multidisciplinary approach, following the Geoswim method (Furlani et al., 2014b, in press) combining snorkel and field surveys, has been used along the coastline of the island of Ustica, Sicily (Italy), to study the occurrence and lateral variations of coastal landforms.

The coastline in the study area is indented, with small bays alternated to headlands and high plunging cliffs. The height of the cliffs and plunging cliffs along the Ustica coastline range between few meters to about 100 meters at Capo Falconiera.

The surveys around the island highlighted a rocky coast characterized by all the geomorphotypes, plunging cliffs, sloping coast, screes, cliff and platforms, pocket beaches. The coastal scenery is characterized by 12 caves opening at the sea level, stacks, arches and rocks.

Geoswim allowed to discover, for the first time in the Mediterranean area, the tidal notch carved in small carbonate inclusions in volcanics, at the present-day sea level. Moreover, MIS 5.5 tidal notches were found at 25 m a.s.l., in Spalmatore sector, as result of the uplift of the island. It develops around two small reliefs which were isolated rocks during MIS 5.5. They are carved in volcanics, but the carbonate was probably removed by karst processes during the last 125 ka and now, the footprint of the old notch remains.

Figure 1. Geomorphological observations along the Ustica coastline (Sicily, Italy).

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Submarine volcanic and faulting activity in the southern Tyrrhenian Sea: Examples from study cases between Ustica Island and the Aeolian Arc and perspectives to improve our knowledge

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An unusual sequence of tectonic and volcanic events occurred in 2002 over a large area of the Southern Tyrrhenian sea. It started on September 6th, 2002 with a M5.9 earthquake located about 40 km SE Ustica, followed by aftershocks with hypocenters aligned along an about100 km northeastern trending fault trace (Rovelli et al., 2004). On October 27th, Mt. Etna started an eruption that lasted about 3 months (Walter et al., 2009). On November 3rd, the submarine hydrothermal system off the island of Panarea began venting a huge amount of CO_2 that killed all the living matter over the area (Caliro et al., 2004). Finally, on December 28th, the volcano of Stromboli started a long lasting eruptive period with a landslide that provoked a tsunami wave (Walter et al., 2009).

All the events, clearly highlighting the close connection between tectonic and volcanic activity, demonstrated how we are still blind to any event (no matter if natural or anthropogenic) occurring at the sea-floor.

The scientific community was able to interpret and model the occurred events although it took a long time (from months to years) due to the lack of information.

Over the epicentral area of the first event (40km SE Ustica island) the communications between Palermo and Roma by the fiber-optic cable were interrupted. After the recovery of the cable, it was observed that about 3 km of cable were locked and the cable was not broken but melted (Fig. 1, a,b) at a temperature estimated to be above 800°C (Favali et al., 2006). This feature was interpreted as the consequence of a volcanic eruption of a new active and still unknown volcano.

Figure 1. The cable "melted" in the epicentral area of the September 2002 earthquake (sea-floor depth 1500m): a) the cable as it was recovered; b) the cable as it had to be (after Favali et al., 2006).

The "anomalous" degassing event Panarea was modeled as a low-energy submarine explosion (Caracausi et al., 2005) induced by magmatic volatiles that intruded the deep hydrothermal reservoir located among the islets 2 miles off the eastern coast of Panarea (Fig. 2). The normal fault, on which the two volcanic edifices of Panarea and Stromboli developed, drove magmatic volatiles (Heinicke et al., 2009).

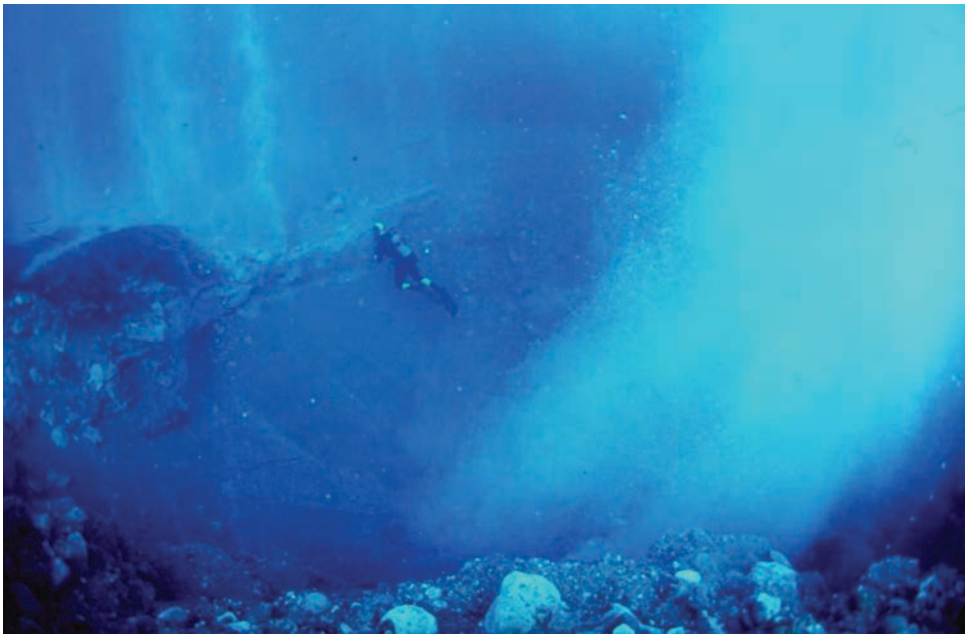

Figure 2. The crater produced by the submarine explosion off the island of Panarea (November 2002). It was about 20 by 15 meters wide and 7 meters deep and vented something like $1x10^9$ litres of CO_2 per day for several months (after Italiano F., 2009).

It is quite evident that we have enough scientific skills to interpret and model events, however, on the other hand if the event occurs beneath the sea surface our observing capability fails, thus it needs to be improved.

Panarea has been the first test site for the development of new technologies for automatic, near real time submarine monitoring (Italiano et al., 2011). An autonomous system composed of a sea-floor observatory and a surface buoy is nowadays producing multidisciplinary data (pCO_2, hydrophone, pH, EC, etc.).

That activity has been carried out in the mainframe of European, national and regional projects. Italy is significantly improving its infrastructures for marine research and monitoring in terms of both number and technology (e.g. www.emso-eu.org and links therein). Our wish is that the enhancement of technological infrastructures may support the scientific researches gaining a better insight into the almost unknown submarine environment where volcanic and tectonic structures are widespread.

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Explosive eruptions and tephra dispersal from Ciomadul (Csomád) volcano, East Carpathians

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During the past ca. 60 ky, violent explosive eruptions occurred at Ciomadul, the youngest volcano in the Carpatho-Pannonian Region, that previously showed a long-lasting (over 500 ky), commonly effusive lava dome activity. Detailed field volcanology, major element pumice glass geochemistry, optically stimulated luminescence and radiocarbon dating as well as unpublished Cassignol-Gillot K-Ar ages prove that the explosive activity started simultaneously with the latest lava dome extrusion events. The explosive stage, related to the older Mohos and the younger St. Ana crater, resulted, among others, in thick successions of pyroclastic-fall and -flow deposits in both proximal and medial/distal localities around the volcano, in some cases characterized by highly silicic (rhyolitic) glass chemical compositions. In particular, a significant two-phase eruption occurred at ca. 31.5 ka, producing pyroclastic flows from vulcanian explosions, disrupting a possible preexisting lava dome in the St. Ana crater, followed by pumiceous fallout from a plinian eruption column. The latest eruptive phase, testified again by dome disruption at St. Ana crater, also included violent phreatomagmatic eruptions that resulted in fine-grained pyroclastic-fall deposits. According to radiocarbon age constraints and preliminary K-Ar dates, the youngest volcanic event occurred at ca. 28-29 ka, some 2,000 years later than the previously suggested last eruption. Tephra dispersal of the latest explosive stage (i.e., between ca. 60-30 ka) occurred toward the southeast, as far as the present-day Dniester delta 350 km from the source.

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Reconstructing 'Atlantis', the Late Bronze Age island of Santorini

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During the Late Bronze Age, the island of Santorini – considered by many as 'Atlantis', the legendary terrain of Plato – had a semi-closed caldera harbour inherited from the 22 ka Plinian Cape Riva eruption, and a central island referred to as 'Pre-Kameni' after the present-day Kameni Islands. In our work, the size and age of the pre-Minoan intracaldera island have been determined by applying a photo-statistical method and high-precision Cassignol-Gillot K-Ar dating. Moreover, using published and own data, the topography of Late Bronze Age Santorini is reconstructed by creating a new digital elevation model. Pre-Kameni and other parts of Santorini were destroyed during the 3.6 ka Minoan eruption, and their fragments were incorporated as lithic clasts in the Minoan pyroclastic deposits. Photo-statistical analysis of these lithics, differentiated by lithology, constrains the volume of Pre-Kameni to ca. 1-2 km^3, smaller than previous estimates. Applying the Cassignol-Gillot K-Ar technique to the most distinguishing black glassy andesite lithics, we propose that the island started to grow soon after the Cape Riva eruption at ca. 20 ka.

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Petrographic and Spectroscopic (FT-IR) study of western Mediterranean obsidians

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In this study we applied petrochemical methods (SEM-EDS; FT-IR) on 19 obsidian flakes, collected at *Ustica* (Sicily), and we compared them with geological samples, which were collected in 12 obsidian sources from *Pantelleria, Lipari*, Sardinia (*Monte Arci*) and *Palmarola*, i.e. the most exploited obsidian mining sites of the ancient world.

A recent paper (Foresta Martin et al., 2016) demonstrated that Ustica island was a major exchange center of obsidians, during the prehistory, despite the absence of obsidianaceous rocks. On this island there are some prehistoric settlements dated from the Neolithic to the Middle Bronze Age (6000- 1200 BC).

We present here analitical data on obsidians: density (analytical balance), visual observation (optical microscope), major elements microanalyses (SEM-EDS) petrographic *characterization* (microlites and vesicle distribution) and hydration profiles (FT-IR). These latter analyses were focused on the determination of H_2O content of the obsidian flakes, in particular where the original tool cut was still visible, spotting analytical points from rim to core, along a transect normal to flake edge. This procedure allows to detect a possible hydration gradient that can give a rough evaluation of the obsidian tool's age since the time of its chipping.

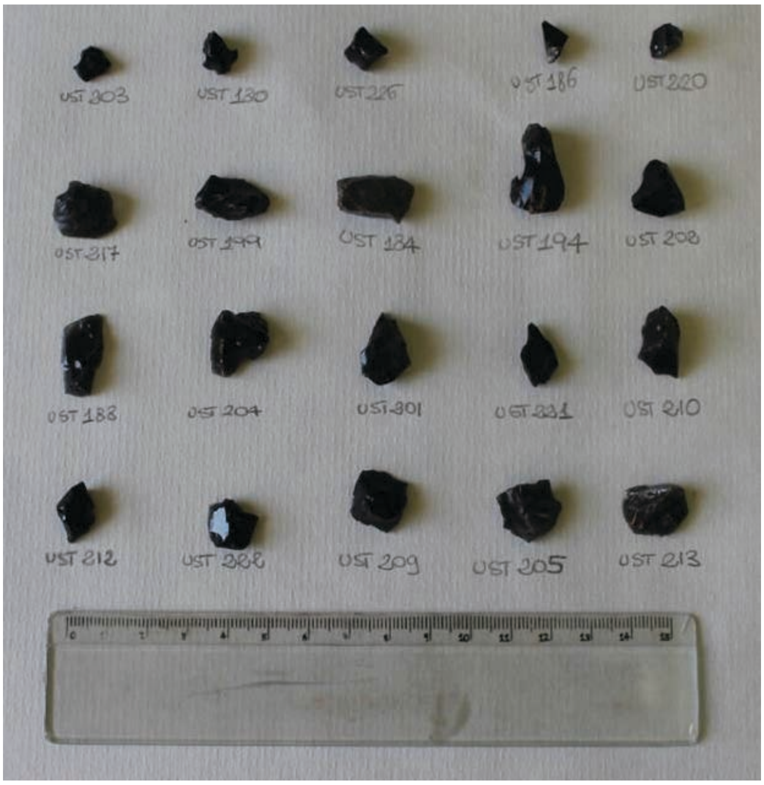

Figure 1. Obsidian Flakes collected at Ustica.

FT-IR results show very low contents in H_2O in the range of 0.3 to 0.1 wt% H_2O from the rim to the core of each flake.

Applying the empirical equation proposed by Friedman and Smith (1960) to an obsidian tool that exhibits hydration rim of 7 micrometers, we obtained an age of about 5000 yrs B.C. that is compatible with Neolitical period.

Regarding the provenances of our obsidian set, density and major elements analyses confirm the literature data (Tykot, 1999 and Foresta Martin et al., 2016) that the provenance of obsidian tools found at Ustica island is by far from Lipari and subordinately from Pantelleria (88% and 12% respectively).

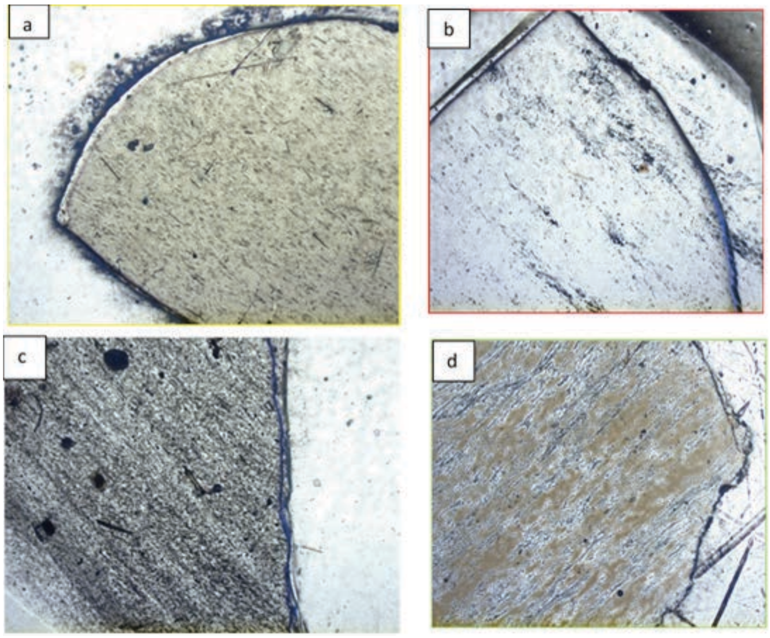

Figure 2. Geological samples collected in obsidian sources from a) Pantelleria, b) Lipari, c) Sardinia (Monte Arci) and d) Palmarola. Visual observation (Optical microscope).

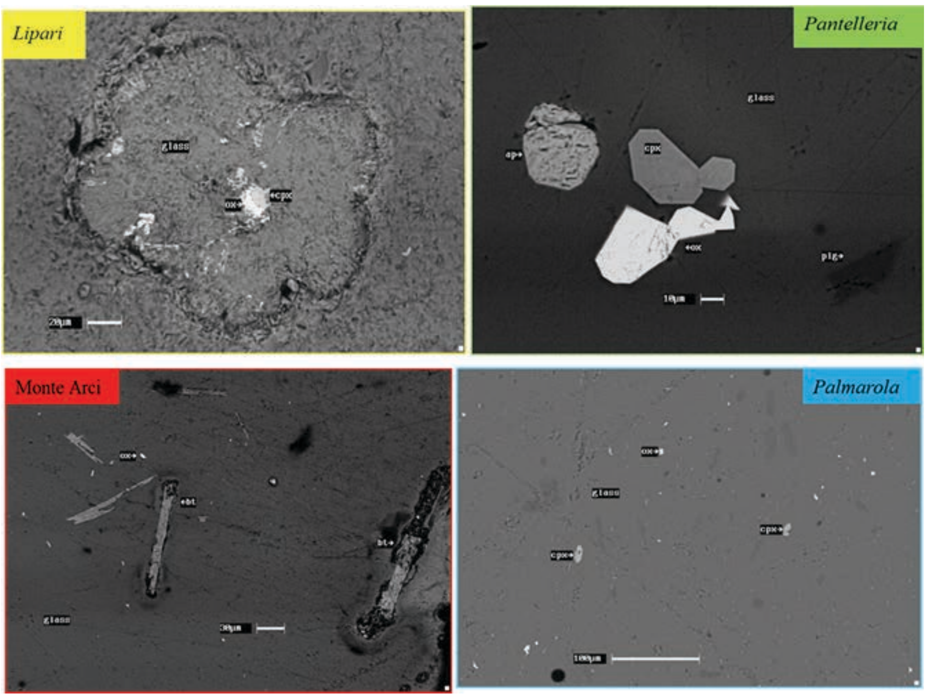

Figure 3. Image SEM-EDS. Petrographic characterization (microlites and vesicle distribution) of the geological samples.

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A study of melt inclusions in Brown Tuffs deposits, Vulcano Island

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Brown Tuffs formations (age 80-5 ka) represent a complex deposit deriving from diluted pyroclastic density currents caused by energetic eruptions with regional importance. These deposits occur in the stratigraphy of the majority of the Aeolian Islands, but dominantly at Lipari and Vulcano islands.

We have analyzed the ash deposits from *Molineddo 3*, a member of Intermediate Brown Tuffs (age 56-20 ka) which crops out at Vulcano island. The deposit is characterized by two typologies of juveniles: (i) brownish pumices with pyroxene and plagioclase phenocrysts and (ii) grey pumices with plagioclase > clinopyroxene crystals.

This study is focused on trace elements and volatile contents determinations in melt inclusion (clinopyroxene hosted). As a whole, melt inclusion compositions are basaltic to trachyandesitic (SiO_2 = 50.2 wt% to 55.4 wt%), in contrast with the rhyolitic composition of matrix glass.

FT-IR analysis of melt inclusions resulted in a surprisingly low volatiles content (H_2O = 0.33 – 1.43 wt%; CO_2 = b.d.l.), supporting the hypothesis of interaction with external water with magma as a possible eruption trigger.

We here add some new data regarding the distal portion of the *Intermediate Brown Tuffs formation*, *Grotta dei Pisani deposit*. This deposit is characterized by coarse ash with loose crystals of pyroxene, plagioclase and olivine. Melt inclusions have a trachyandesite composition (SiO_2 = 53.4 wt% to 57.4 wt%), slightly more evolved in contrast with these contained phenocrysts in proximal sampling sites. This suggests an efficient cooling – evolution of magma, where fractional crystallization is controlled by clinopyroxene's separation.

Volatile contents in melt inclusions are also measured; they resulted in a low content (H_2O = 0.33-0.78 wt%; CO_2 = b.d.l.), in the range of those measured in proximal deposit.

Trace elements in MI of *Molineddo 3* were analyzed with laser ablation technique (LA-ICP-MS); the resulting patterns, in particular highly incompatible trace elements ratios, show the typical signature of subduction-related magmas.

Finally we made an attempt to calculate distribution coefficients between clinopyroxene and melt inclusions ($Kd^{cpx/liq}$). If compared with literature data Kds of some key elements (Sc, Cr, Ni) are consistenly higher.

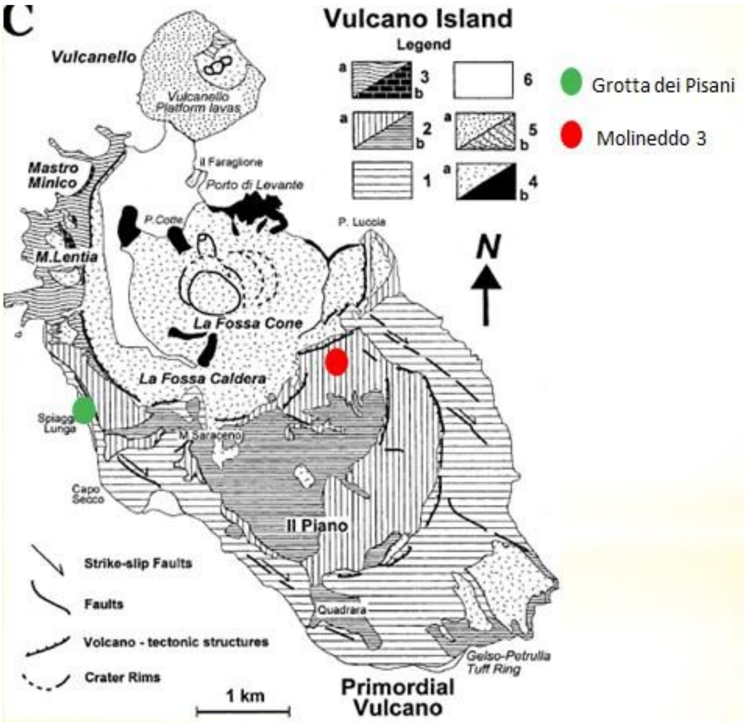

Figure 1. Geological Map of Vulcano Island, where sampling points are indicated.

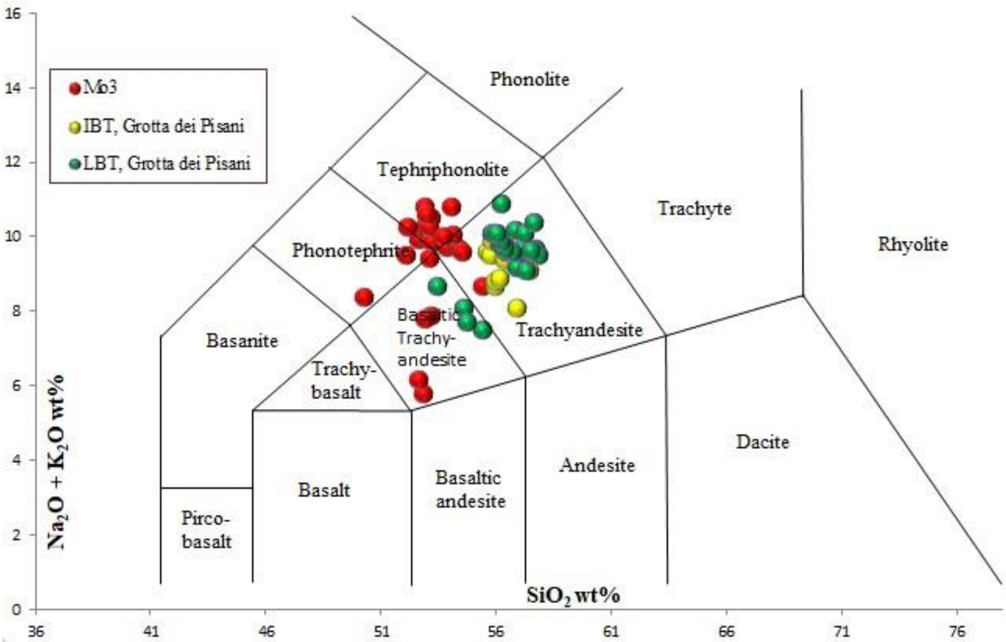

Figure 2. Total Alkali versus Silica Diagram (TAS). Red cicles indicate the melt inclusion composition of Molineddo 3 member; Green and yellow cicles indicate the melt inclusion composition of Grotta dei Pisani members, LBT and IBT respectively.

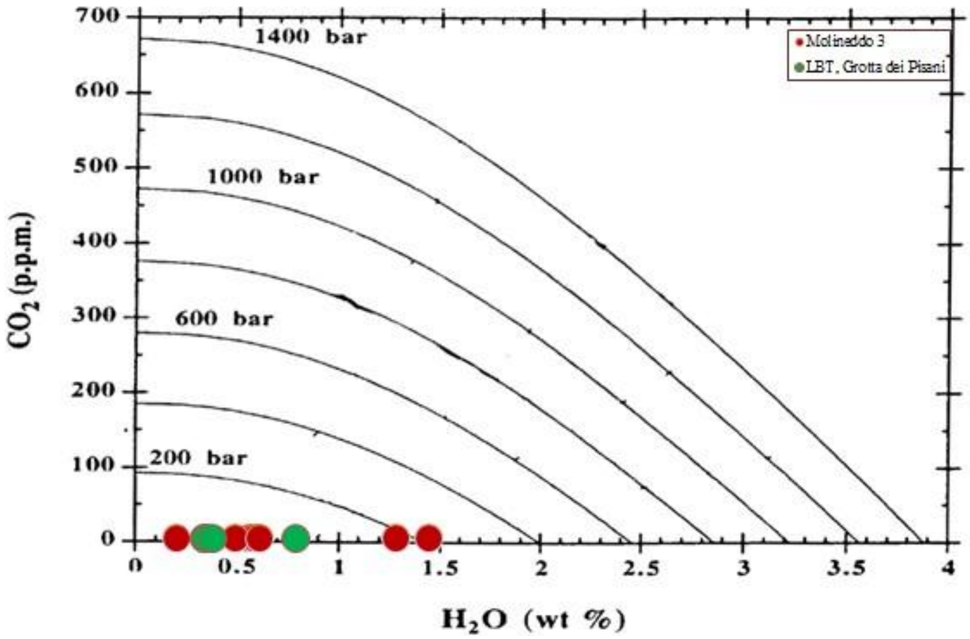

Figure 3. H_2O-CO_2 concetrations-pressure (Lowenstern, 1995), with saturation isobars of H_2O and CO_2.

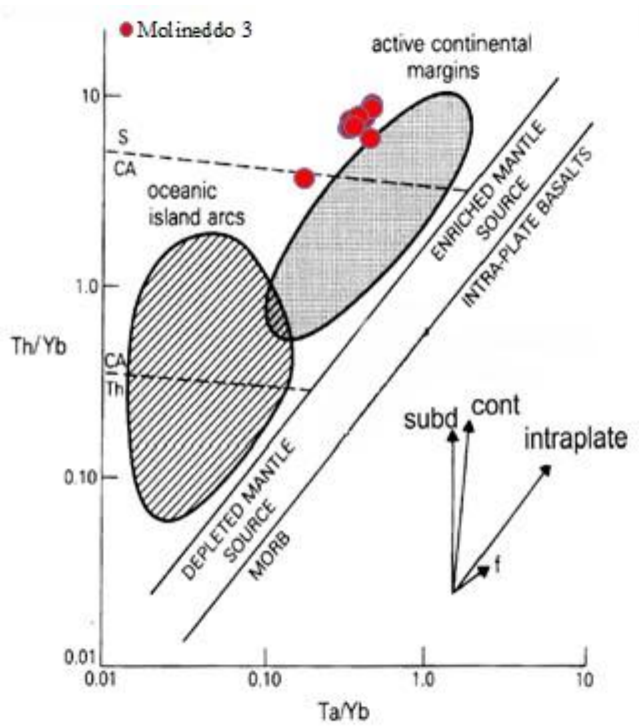

Figure 4. Th/YB versus Ta/Yb diagram (Pearce et al., 1983). The diagram highlights the subduction signature of Molineddo 3 melts.

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Tectonic structures and anomalous degassing of Radon gas from soil in Ustica Island (Sicily, Italy)

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The seismic sequence marked by the M_w 5.9 mainshock occurred off the NW Sicilian coasts on September 2002 is the last significant evidence of active tectonic activity recorded nearby the volcanic island of Ustica. Although the epicenter was located far away from the island, the break in the epicentral area of a fiber-optical cable deployed between Palermo and Rome (Favali et al., 2006) is an indication that the volcano tectonic activity of the area might not be extinct. The cable, in fact, was not simply broken but melted at a temperature above 850°C (Favali et al., 2006). The last eruptive activity of Ustica island is dated 130 ka BP, and involved the north-eastern portion of the Island with a phreatomagmatic eruption developed in a shallow marine environment that formed the Falconiera tuff-cone (De Vita & Foresta Martin, 2017).

Ustica was affected by an intense tectonic activity during Pleistocene, with dominant E-W and NE-SW oriented faults and subordinately NW-SE and N-S trending fault systems (De Vita, 1993; De Vita et al., 1995). This structural framework can be explained by a sinistral transtension regime related to the Tyrrhenian back-arc-accretionary wedge system (Doglioni, 1991).

The presence of warm gas emissions over the Arso area are considered as clues of residual volcanic activity. Recent investigations (Etiope et al, 1999; 2002) highlighted the presence of an active degassing of deep-originated gases (CO_2 and CH_4) besides a weak venting of steam.

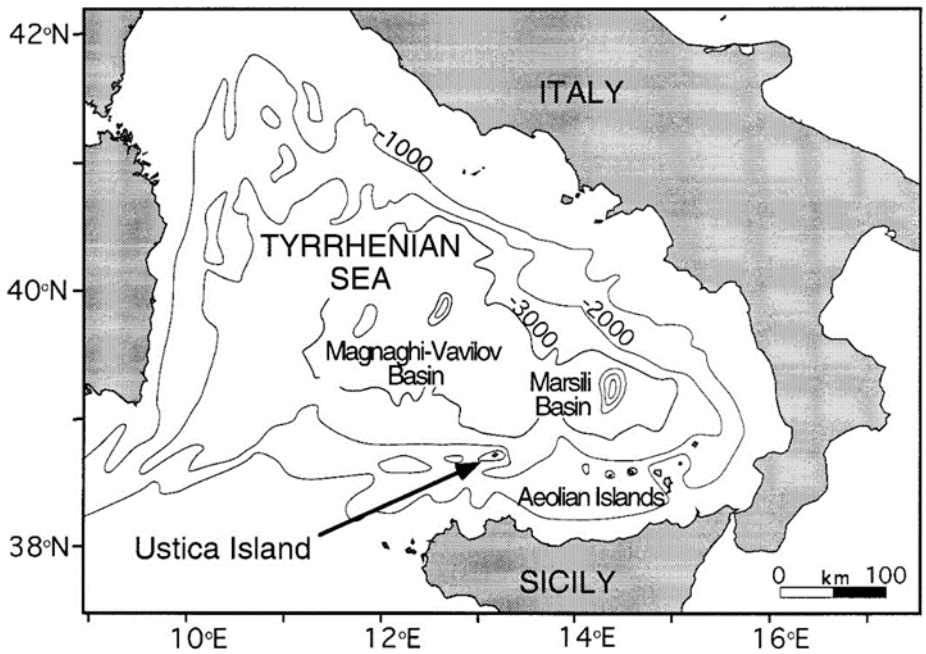

Figure 1. Location of Ustica Island in the southern Tyrrhenian Sea (modified from Catalano et al., 1998).

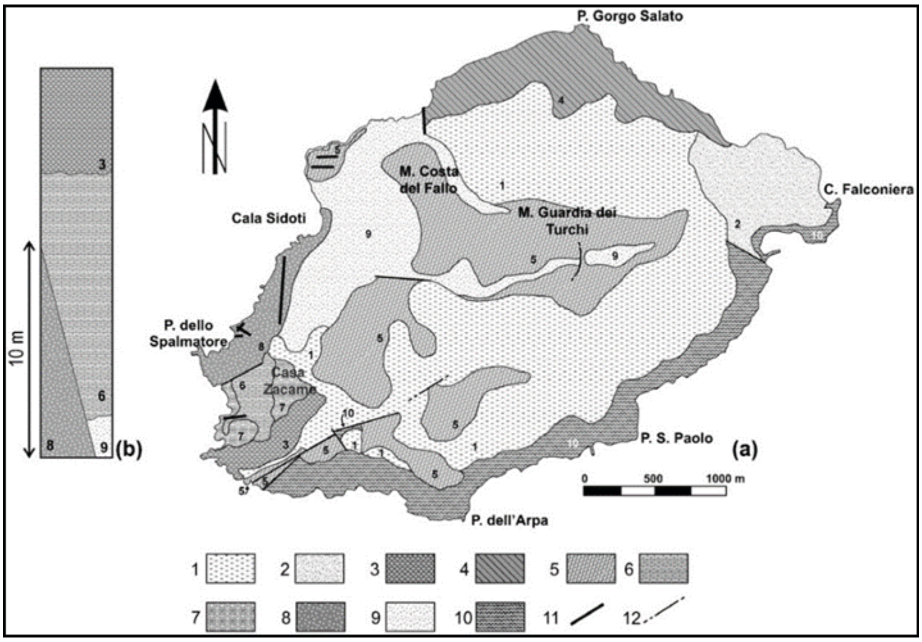

Figure 2. (a) Geological sketch map of Ustica Island (modified from Cinque et al., 1988; DeVita et al., 1998 with unpublished data of the authors); (b) stratigraphic relationships in the study area. (1) Principal marine terraces (200–350 ka); (2) Capo Falconiera tuff (130 ka); (3) Casa Zacame basaltic lavas (250 ka); (4) Tramontana and Cala del Camposanto mugearitic lavas (250–400 ka); (5) M. Costa del Fallo hawaiitic lavas (300–500 ka); (6) Villaggio subaerial hawaiitic lavas (300 ka); (7) Case Alaimo tuff (N 300 ka); (8) Cala Sidoti hawaiitic hyaloclastites and pillow lavas (420 ka); (9) M. Costa del Fallo tuff (500 ka); (10) Torre S. Maria and Punta Falconiera submarine basaltic lavas (550–735 ka); (11) dikes; (12) faults.

We carried out a preliminary study to put in evidence possible relationships between anomalous soil degassing and active volcano-tectonic structures. During the field investigations, new data about soil Radon degassing were collected by an α-detector (AlphaGUARD Radon Monitor).

Previous gamma-ray spectrometric measurements have been performed on rocks and soils (Bellia et al.,1997) to quantify the natural radionuclides concentrations. The results have shown the following ranges: ^{238}U (15-164 Bq/kg), ^{232}Th (16-174 Bq/kg) and ^{40}K (201-1350 Bq/kg). In general, the lowest values are found in the basaltic rocks and the highest ones in trachytes samples, while the indoor radon measurements have a mean value of 190 Bq/mc, but about 50% of the values are below 100 Bq/mc (Bellia et al., 1997). Isotopic analyses of ^{13}C of CO_2 and CH_4, isotopic ratio of $^3He/^4He$ (ground gas and deep seawater) provided some information about pattern of crustal-mantle degassing and interactions pointing toward a contribution from a deep (mantle-type) component (Etiope et al., 2002).

In general, soil degassing does not show any evident manifestations on surface, such as fumaroles. In fact, the mean CO_2 flux density level of Ustica Island is lower than the other active volcanoes of Southern Italy. Between 1997 and 1999, only two surveys of soil-gas diffuse (CO_2 and CH_4) were carried out here, to observe the degassing role of faults and fracture systems, confirming that the Arso fault is the principal degassing structure.

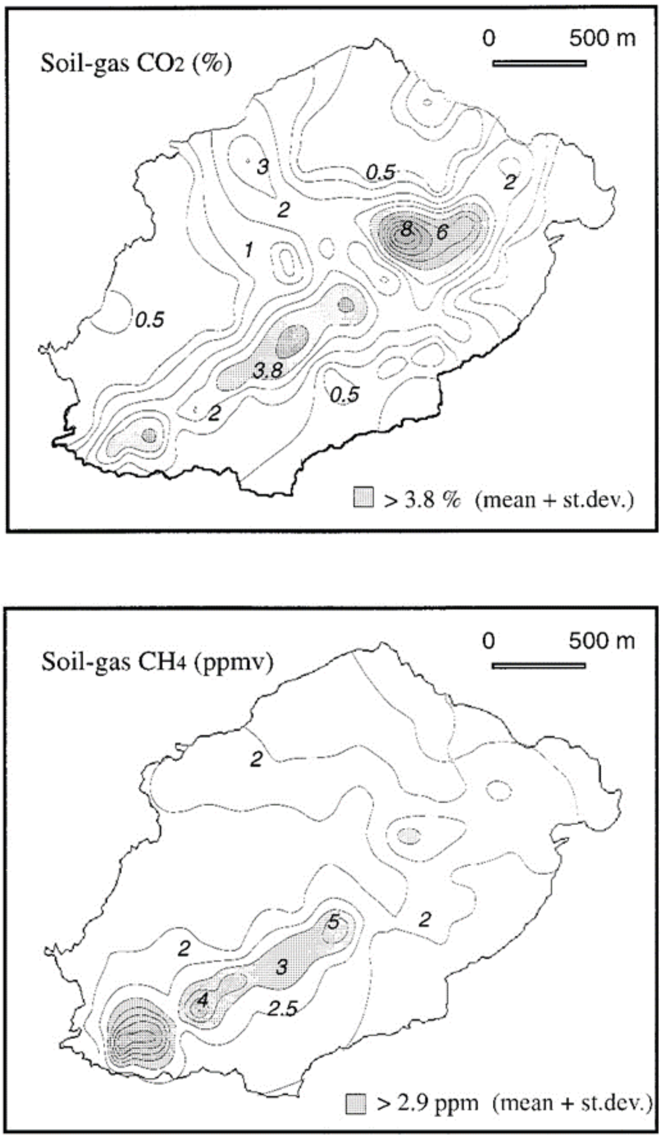

Figure 3a,b. Soil-gas areal distribution: CO_2 and CH_4. Contour lines are obtained by the kriging interpolation method. Major gas concentrations occur in the Arso Fault zone; the CO_2 linear trend suggests continuation of a gas-bearing structure up to the NE sector of the island (Etiope et al.,1999).

In conclusions, preliminary data confirm a real correlation between the Radon concentration from soil emissions and the active tectonic structures, in agreement with the previous studies (Etiope et al., 1999; Etiope et al., 2002; Etiope et al., 2007). The highest ^{222}Rn values are detected inside the Arso fault zone, until Piano Cardone and Mt. Guardia ranging from 17.300 +/- 1190 to 80.300 +/- 4140 Bq/mc; relatively low values were found in Falconiera zone in the range from 762+/-136 to 1600+/-280 Bq/mc. These soil degassing anomalies suggest that, the Arso Fault and the local expression of SW–NE structural element, crossing the whole island until the Falconiera zone, are still active gas-bearing. Other surveys will be needed to complete the map of soil-gas emissions, in relation to the structural setting of this island.

Figure 4. Sampling sites of Radon concentrations from soil emissions in Ustica Island (Sicily, Italy).

SITES	Lat	Lat	Long	Long	Altitudine (m)	Rn	Temp °C	Hr %	P (mbar)
UST 1	38,711	44°59'13.592"	13,171	10°44'49.700"	121	961 +/- 143	32	49	1002
UST 2	38,709	44°59'13.592"	13,173	10°44'49.700"	104	5,020 +/- 807	34	38	998
UST 3	38,708	44°59'13.5900"	13,182	10°44'49.6980"	227	633 +/- 341	32	44	990
UST 4	38,707	44°59'13.5900"	13,181	10°44'49.6980"	228	38,150 +/- 1855	36	37	990
UST 5	38,709	44°59'13.5900"	13,198	10°44'49.6980"	46	1,400 +/- 242	36	32	1011
UST 6	38,711	44°59'13.5900"	13,197	10°44'49.6980"	150	762 +/- 136	32	42	1000
UST 7	38,711	44°59'13.5900"	13,194	10°44'49.6980"	90	1,600 +/- 280	36	34	1006
UST 8	38,709	44°59'13.5900"	13,198	10°44'49.6980"	46	1,500 +/-528	36	34	1031
UST 9	38,693	44°59'13.5900"	13,157	10°44'49.6980"	20	17,300 +/-1190	41	25	1041
UST 10	38695	44°59'13.5900"	13163	10°44'49.6980"	73	7,460 +/- 1190	41	23	1008
UST 11	38,699	44°59'13.5900"	13,171	10°44'49.6980"	108	4,060 +/- 470	36	31	1003
UST 12	38,706	44°59'13.5900"	13,187	10°44'49.6980"	117	80,300 +/- 4140	28	47	1003

Table 1. Sampling sites and their range of Radon concentration from soil emissions with weather parameters.

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The volcanic events that marked the human history of Lipari (Aeolian Islands)

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The volcanic risk to which the Aeolian archipelago is subjected requires a careful consideration in the multidisciplinary fields about the possible destructive events that are likely to occur in the broad span of time in which volcanism travelled alongside local anthropic history: the last 7.5 ka.

From the Upper Neolithic, numerous cultural facies have been replaced seamlessly, except for some periods when the islands have returned almost uninhabited. These situations can be better explained in the presence of unforeseeable events caused by the volcanic nature of the archipelago.

Human history in Lipari has undergone three significant breaks, characterized by strong demographic crises and cultural changes (Bernabò Brea and Cavalier, 1960, 1965):

1. between 2700 and 2500 BC, in the passage from the Culture of Diana (prospered in the Mediterranean for over a millennium) to the Pianoconte Culture;
2. between the IX and VI centuries BC, in the period preceding the Greek re-foundation;
3. between VI and X century AD, in the period preceding the Norman re-foundation.

In the first case there is the abandonment of the inhabited centre of Lipari (Diana quarter) toward internal elevated areas, repaired from the potential destructive effects, direct and indirect, of volcanic activity (Manni, 2015). Significant upheavals affected Stromboli during this period. After an important eruptive phase that ended about 7 ka, the volcano reached the maximum volumetric expansion of the N sector that caused a structural instability and massive breakdowns of this sector (Tinti, 2002; Francalanci et al., 2013). Around 3000 BC, one of the sector collapses formed the Sciara del Fuoco scar and led the birth of the present volcanic centre (Tibaldi et al., 2001).

After an inactivity period, a new sector collapse marked the resuming of volcanic activity in the NE sector of Stromboli (Francalanci et al., 2013). Perhaps this event can be considered among the causes that led, around the IX century BC, to the second and worst depopulation of Aeolian history. Numerical simulations (Tinti et al., 2002) confirmed the potentially disastrous effects of tsunami caused by Stromboli collapse along the Aeolian and the Tyrrhenian SE coasts.

The third major demographic crisis occurring in the Early Middle Ages is generally attributable to the socio-economic conditions and, specifically, to the resuming of the volcanic activity on Lipari island in the eruptive centres of Pirrera and Monte Pelato that arise in the NE sector of the island. The analysis of coeval sources has proved to be useful in reconstructing the recent eruptive history of Lipari and, in particular, for dating of the last eruption: the Rocche Rosse obsidian flow in 1264-65. In particular, from the VI century, a shifting of the settlement occurred to the rural areas less exposed to volcanic activity, and to develop several sites in the nearby Salina Island, because of the NE side of Lipari was occupied by volcanic activity until the XIII century (Tanguy et al., 2002; Bigazzi et al., 2003), and was left totally uninhabited and uncultivated until the XVI century (Iacolino, 2007).

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Evolution of the magma feeding system during a Plinian eruption: the case of Pomici di Avellino eruption of Somma-Vesuvius, Italy

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Numerical simulations of magma flow in a conduit, combined with volcanological and geological data, allow the first description of feeding system evolution during a sustained phase of an explosive eruption. The method was applied to the Plinian phase of the Pomici di Avellino eruption (PdA, 3945 ± 10 cal yr BP) from Somma-Vesuvius (Italy). Numerical simulations produced a mass discharge rate (MDR) similar to that derived from field data. Further geological constraints come from the volume and types of lithic components in the fall deposits, which were used to constrain the depth of fragmentation and conduit erosion rate.

Three stable geometric configurations of the feeding system were assessed (best solutions) for Eruptive Units 2 and 3 (EU2, EU3), which form the magmatic Plinian phase of PdA eruption. They describe the conduit system geometry at the time of deposition of EU2 base, EU2 top, and EU3. A 7-km deep dyke (length 2a = 200-400 m, width 2b = 10-12 m), connecting the magma chamber to the surface, characterised the feeding system at the onset of the Plinian phase (EU2 base). The feeding system rapidly evolved into hybrid geometry, with a deeper dyke (2a = 600-800 m, 2b = 50 m) and a shallower cylindrical conduit (diameter D=50 m, depth TL=2100 m), during the eruption of the EU2 top. The deeper dyke reached the dimensions of 2a = 2000 m and 2b = 60 m at EU3 peak MDR, when the shallower cylinder had enlarged to a diameter of 60 m and a depth of 3000 m.

The changes in feeding system geometry indicate a partitioning of the driving pressure of the eruption, which affected both moving magma to the surface and dyke growth. This implies that a significant portion of the magma injected from the magma chamber filled the enlarging dyke before it erupted to the surface. In this model, the lower dyke acted as a sort of magma "capacitor" in which the magma was stored briefly before accelerating to the cylindrical conduit and erupting. The capacitor effect of the lower dyke implies longer times of transit for the erupting magma, which also underwent different steps of decompression. On the other hand, the decompression of magma within the capacitor provided the driving pressure to maintain the flow into the upper cylindrical conduit, even when the base of the dyke was closed due to a drop in driving pressure from progressive emptying of the magma chamber. The shallower cylindrical conduit was shaped through the erosion of conduit wall rocks at and above the fragmentation level. Using the lithic volume and duration of EU3, the erosion rate of shallower cylindrical conduit was calculated at ca. 5 × 103 m3/s. The outcomes of this work represent an important baseline for further petrologic and geophysical studies devoted to the comprehension of processes driving volcanic eruptions.

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Risk perception for volcanic hazards on active volcanic islands: Ischia, Lipari, Stromboli, Vulcano (Italy), La Reunion (France) and San Miguel (Portugal)

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The social dimension of risk is a complex topic that has been investigated since the early 40's, and perception of risk has become a conventional term, defined as combination of social, economic, cultural and environmental factors. Qualitative assessment of people's perception has been increasingly integrated in natural hazards studies, while volcanic risk perception have been widely investigated all over the world, mainly in the last twenty years, analyzing and assessing volcanic risk perception from different perspectives.
Active volcanic islands are an interesting and peculiar environment to study risk perception. We present some results and considerations on a survey carried out in some islands.
The survey methodology consisted in questionnaires designed to measure variables such as: salience of the hazard; risk perception (rating both the likelihood and severity of future eruptions perceived); knowledge of the hazard and of hazard mitigation strategies; perceived preparedness of and trust in officials, scientist and the media: sense of community.

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Risk management issues on tourist regions with explosive volcanism: The Teide's 2004 unrest, Canary Islands

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Teide volcano (Tenerife, Canary Islands) was identified by IAVCEI as one of Decade Volcanoes (16) due to their history of large, destructive eruptions and proximity to populated areas. Teide was also included as one of the 6th European laboratory volcanoes (ESF). Both initiatives increased the Teide-Pico Viejo Volcanic System Complex (TP-VSC) knowledge, thanks to the research networks deployed at that time, which allowed to determine with the maximum possible accuracy the internal structure, the evolution and present state (base level) of the Teide eruptive system.

A remarkable increase in seismicity (besides of tremor episodes never observed before) was detected on 2000 and was identified as a TP-VSC reactivation. However, this fact was not evident for population until 2004, when many M3 earthquakes were felt, producing a strong shock on authorities and people. Until then TP-VSC has been considered a no active volcanic system, so many people realized for the first time they were living in an active volcanic island. Despite of the available research papers about TP-VSC and its capacity to produce VEI > 4 eruptions in a high risk context, neither emergency plans nor mitigation strategies existed, including communication or educative plans. The authorities tried to divert the public attention about the observed volcanic activity, avoiding to talk about the TP-VSC activity (earthquakes, fumaroles, etc.). According to the authorities, in case of eruption, it might be quiet (effusive) and located in the Northwest rift of the island (lesser inhabitants area). This situation was internationally known and some alarming press articles were issued, describing Tenerife as "Terrorife" (Christie, Michael, "Welcome to Terrorife". Daily Record, 16 June 2004, U.K.), and causing damage in the tourist economic activity.

However, the 2004-unrest brought some important improvements at all levels. First, and due to the initial lack of public information, a social forum webpage was used as a meeting point for whom wanted to know more about the volcanic nature of the island and what was happening. This initiative allowed to inform and educate a lot of people and tourists. Today, and supported by scientists, a non-profit social organization, especially dedicated to volcanoes and natural hazards, (www.volcanesdecanarias.com) is active. The first Volcanic Risk Educative Guide was published, the first regional emergency volcanic plan was approved (2010). Finally, new permanent volcanic monitoring networks have been deployed (IGN, INVOLCAN, CSIC).

The volcanic activity level TP-VSC still continues with higher and lower periods of activity, but there is still a great problem related to the public communication, mainly because this type of activity is managed as a problem for the tourist sector.

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Seismic and volcanic activity forecasting: Scientific advances and examples obtained in different types of active volcanoes

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Forecasting is a problem that has been addressed worldwide from different perspectives. Significant advances have been obtained after the introduction of complexity theory, and power-law distributions of different parameters. In particular, frequency-magnitude power-law statistics evidences, the scale-invariance and self organization of seismicity, and brittle fracture models show a precursory causal evolution of strain characterized by an accelerating process culminating in a catastrophic failure. These characteristics of organization have allowed the development of forecasting tools. For instance, the Failure Forecast Method permits forecasting volcanic activity from the precursory accelerating rate of different strain-related parameters such as seismic amplitude, energy and spectra, Other types of analysis such as the base level noise or the dynamical analysis and Self-Organizing Maps have proved useful to identify long-term precursory changes and families of events, or even to forecast potentially destructive larger-magnitude volcano-tectonic earthquakes. The choice of the method to be used depends in each case on a preliminary assessment of the physics controlling the volcanic activity and the type of available data. This requires at times developing new methods to deal with particular situations. We present some examples of these forecasting methods applied to different volcanoes, and how that experience has been used to improve the hardware and software developed for that purpose. With this aim we have selected the following volcanoes: Villarrica and Llaima (Chile), Tungurahua (Ecuador), Popocatepetl and Colima (México), Etna and Stromboli (Italia), Teide and El Hierro (Spain).

The recent volcanic and seismic unrest at El Hierro (Canary Islands; 2011-2016) provided an opportunity to use these real-time tools to follow up the development of such a complex phenomenon since its onset in July 2011, and to assist forecast-based decision-making. During this volcanic process, we developed a robust method to forecast the occurrence of the largest-magnitude earthquake, to objectively communicate the hazard. Indeed, the follow-up of a volcanic activity has two main lines, one is specifically scientific, while the other is focused on the management of the risk posed by the activity. The latter must generate decision factors in quasi-real time and include criteria and communication procedures to advise authorities and warn the populace with the required earliness. Such timing is determined by the type of necessary preventive actions (e.g. hours in the case of closing of a road in a zone of probable landslides, or days for a possible evacuation).

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The Value of historical for risk reduction: the 1600 Huaynaputina eruption (Perù)

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On the 14th of February of 1600, one of the most explosive eruptions occurred in historic times in South America; an extraordinary event that plunged the city of Arequipa (Peru) and surrounding villages into crisis for months and its economic consequences were sustained for years. The volcano in question is the Huaynaputina (16º37'S-70º51'W), although many historical sources indicate that this activity was associated with the volcano of Arequipa or Omate, among others. The aim of this research is demonstrating how historical documents and an adequate working methodology, may aid to reduce disasters.

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Volume-time distribution and rheological behavior of lava flows and domes from Ischia Island (Campania, Italy)

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Ischia island is a densely inhabited active volcano, hosting a permanent population of about 50'000 people wich increases during summer thanks also to the thriving farms, tourist resorts and commercial enterprises. Nonetheless, the risk associated with lava flows in case of renewal of activity is relatively understudied.

In Ischia the archaeological investigation is the key to better understand especially the past 6 ka. In fact in the literature, archaeology has been used to precisely date volcanic events that were closely spaced in time.

One of the most characteristic and open issue of Ischia is that the magmas with similar compositions and degree of porphiricity, can give origin to a set of different eruption styles, from lava flows to even plinian eruptions.

We present the first analysis of the distribution of volumes of lava units during the last 10 ky. These volumes have been calculated by masking a DEM with the lava extent and calculating the volume values above a set of reference plains.

We also present a textural analysis and a rheological study of natural and partially-crystallized magma from the Arso Lavas (1302 A.D) and Zaro Lava domes and flows (6 ± 2.2 ka). The present work aims at investigating the role of the crystal cargo in the rheological behavior of these lava flows.

The eruption duration of Arso Lavas is known because these are the product of the last eruption at Ischia, which occurred in 1302 A.D. With this information it is possible to set constraints to a rheological model that can be extended to estimate duration and behavior of other lava flows in the island, with similar physical properties and chemical composition.

Zaro Lava domes and flows is a lava field located in the north-western corner of the island, it is composed of lavas that show a very high degree of porphiricity and, therefore, it has been selected as a second case study for this investigation.

The textural analysis with the crystal and vesicle size distribution is the starting point for the characterization of both of these units and for estimating the rheological properties during the transport and the emplacement.

One of the important results expected from this work in progress is the relationship, in a simplified model, between the velocity of the lava flows and terrain slope. All the data, helpful to apply the Jeffreys equation, relative to the environment and to the area of emplacement, like position, geometry and slope of the channel, have been evaluated by a GIS analysis.

The volcanic system of the Island is still active, with intense volcanism in historical times, earthquakes and thermal springs, for this reason, most of these results may be used by the Department of Civil Protection for the risk mitigation in this Mediterranean area.

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Soil gas investigations at Campi Flegrei caldera (Italy)

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Campi Flegrei is a caldera near Naples formed by two main collapses, following the huge eruptions that emitted the Campanian Ignimbrite (~39,000 years B.P.) and the Yellow Tuff Ignimbrite (~15,000 years B.P.). Only one eruption occurred at Campi Flegrei in historical time (1538 A.D.) forming the Monte Nuovo cone, where a future eruptive vent might open nearby in case of volcanic reactivation. This caldera is famous worldwide for its recurrent uplift episodes, called bradyseisms, accompanied by a marked shallow seismicity and increase of fumarolic activity. Since 2000 a new uplift began accompanied by chemical-physical changes in fumarolic activity indicating a fluid pressure increase in the hydrothermal system. In 2009 the uplift temporarily stopped (no reversal signals were recorded) to sharply re-increase in 2012-2013 and again from 2014 to 2016. Shallow seismic crises were also periodically recorded.

In the period 2014 - 2017 some diffuse soil CO_2 flux surveys, by accumulation chamber method, have been carried out over most of the volcanic edifices located within the Campi Flegrei caldera such as Monte Nuovo, Agnano - Monte Spina, Solforata, Fondi di Baia and Astroni. The main aims of this investigation were to ascertain where anomalous degassing was occurring in this area, to define the preferential paths of gas upraise with respect to the structural framework and to estimate the present total diffuse gas output. Results show that all the investigated areas are affected by anomalous CO_2 degassing. The highest CO_2 soil flux values have been found at Solforata, which is characterized by high-temperature and widespread fumarolic activity, and where the diffuse CO_2 output was estimated to 100 ton/day. Monte Nuovo and Agnano - Monte Spina, considered the most likely sites of future eruptive vents, release 12 and 18 tons/day of CO_2 respectively. At Baia and Astroni the total diffuse CO_2 output is estimated to 15 and 6,5 tons/day respectively. The distribution of the soil CO_2 flux anomalies indicates the location of the main degassing structures and we think that it would be important to include these structures as target areas in the volcano monitoring system of Campi Flegrei and to regularly repeate soil CO_2 flux surveys from them.

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Lava pebbles used in past human activities (case studies of Middle Bronze Age and Roman Period): witnesses of an old trachyte effusive activity of Mt. Somma volcano

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Recent petro-archaeometric studies performed in archaeological sites of the southern and south-eastern sectors of Somma-Vesuvius volcano have emphasized the presence of a multitude of volcanic rocks (lavas) used for different purposes in the past human activities, compatible with the Somma-Vesuvius magmas erupted earlier than 8 ka BP. Some examples are represented by pebbles employed as lateral supports for palings, weights for fishing and counterweights, stone base in building foundations, millstones, etc. Two case studies comprise pebbles in (i) the Longola settlement (Balassone et al, 2015), a protohistoric perifluvial village (from the Middle Bronze Age to the sixth century BC) located near Poggiomarino and (ii) the famous Villas of Oplontis (Roman period) built along the ancient coastal cliff of Torre Annunziata.

Despite the obvious irrelevance in these archaeological sites of so many stone findings belonging to the near Somma-Vesuvius, the identification of a group of trachyte lava pebbles - not matching with any outcropping lithostratigraphic units of the volcano - can represent a relevant topic in its volcanological evolution/chronology. As a matter of fact, similar trachyte magmas were frequently erupted as pyroclastic products during the explosive Somma activity, but an old trachyte effusive phase does not find a clear evidence as outcrops of lava flows stricto sensu.

Trachyte lava pebbles found at Longola and Oplontis are generally subaphyric to poorly porphyritic, with a feldspathic pilotaxitic to felty groundmass. The fundamental minerals are represented by sanidine, plagioclase and green clinopyroxene; in some cases, amphibole and biotite are also detected, together with various felspathoid phases. Accessory minerals consist of opaque minerals and rare titanite. In the TAS classification diagram these samples straddle the fields of trachyte and phonolite, showing a K2O/Na2O ranging between 1 and 2.7 wt.%.

Although trachyte compositions among the oldest products of Somma-Vesuvius were only found as pyroclastic products, the trachyte lava pebbles detected in the investigated archaeological sites show a strong affinity with the magmas erupted during some of the oldest Plinian explosive events (e.g. "Pomici Basali" and "Greenish Pumice" Plinian and sub-Plinian eruptions). It is plausible that the studied trachyte lava pebbles might represent the eroded lavas of some pericalderic effusive activity of Somma-Vesuvius then disappeared because of successive caldera collapses or simply covered by younger extrusives. However, it is also worth noting that pre-"Pomici Basali" trachyte lavas were recorded by Sulpizio (pers. comm.) in the northern, outer sectors of the Mt. Somma rim.

Witnesses of this effusive activity, which was partly/completely eroded and/or buried by the activity younger than 8 ka BP, could be also identified in searching and studying lithic clasts within pyroclastic deposits of the volcano, as well as in other archaeological contexts.

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Paleomagnetic Dating of the Neostromboli Sequence

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The Stromboli volcano is characterized by "Strombolian" eruptions, major explosions and paroxysms, sometimes interrupted by effusive activity. However, in the Neostromboli succession, eccentric vents opened along the volcano slopes. As each type of activity is related to a specific volcanic hazard, the detailed study of the volcanic stratigraphy is useful for the identification of "evolutive cycles".

This study is focused on the paleomagnetic dating of the Neostromboli succession. Some units (such as the San Vincenzo Formation), were already dated by isotopic and paleomagnetic methods, but the different dating techniques yielded remarkably different ages. For other units, such as the Ginostra and Vallonazzo Formations, a single dating has been reported, though their activity presumably spread out over several centuries/millennia.

We have paleomagnetically dated 40 sites, using 18 paleomagnetic site-mean directions already published by Speranza et al. (2008), and 22 new paleomagnetic directions obtained by us. Paleomagnetic dating was performed by comparing paleomagnetic directions with a recent geomagnetic field model (SHA.DIF.14K, Pavon-Carrasco et al., 2014), which yields an improved dating resolution for ages within the last 14 ka.

In order to verify the reliability of our dating method, we carried out a test with the 1985 and 2007 lava flows, when the direction of the geomagnetic field was precisely known. Such test revealed that the paleomagnetic directions from Stromboli lavas are indeed similar to the coeval geomagnetic field direction as inferred from global models. The data quantified the "inclination flattening" phaenomenon on Stromboli Island to an angular value < 3°, and confirmed that the paleomagnetic directions from several (≥3) sites should be averaged in order to obtain a paleomagnetic direction statistically indistinguishable from the coeval field direction.

The results show that the entire succession developed from ≈9 ka BP (Figure 1), while previous literature data (Gillot & Keller, 1993) yielded a 14 ka BP activity onset age. The San Vincenzo Formation is paleomagnetically dated at 6891-6651 or 6422-6073 yr BP, in agreement with previous paleomagnetic dating by Speranza et a., 2008 (6.2 ka BP), and younger than Ar/Ar dating by Calvari et al., 2011 (12.5±2.6 ka BP). It follows that the San Vincenzo Formation is younger than Nel Cannestrà Formation (dated at 7905-7746 yr BP), and could be the last Neostromboli eccentric eruption occurring just before the Secche di Lazzaro phreatomagmatic eruption.

The Secche di Lazzaro Formation, that has been associated with the last main Sciara del Fuoco collapse, was dated at 6409-6239 yr BP. Furthermore, the thermal demagnetization of the matrix from of the lower unit member yields a >600°C emplacement temperature that turns out to be inconsistent with temperatures (<140°C) estimated by Porreca et al., 2006 through the paleomagnetism of lava lithics. Thus, it is possible that the thin sampled unit had a too small volume to heat the lithics to the same deposit temperature.

New ages were also obtained for the Filo del Fuoco, Ginostra, Labronzo and Vallonazzo formations, as well as for lavas exposed near the Ginostra village.

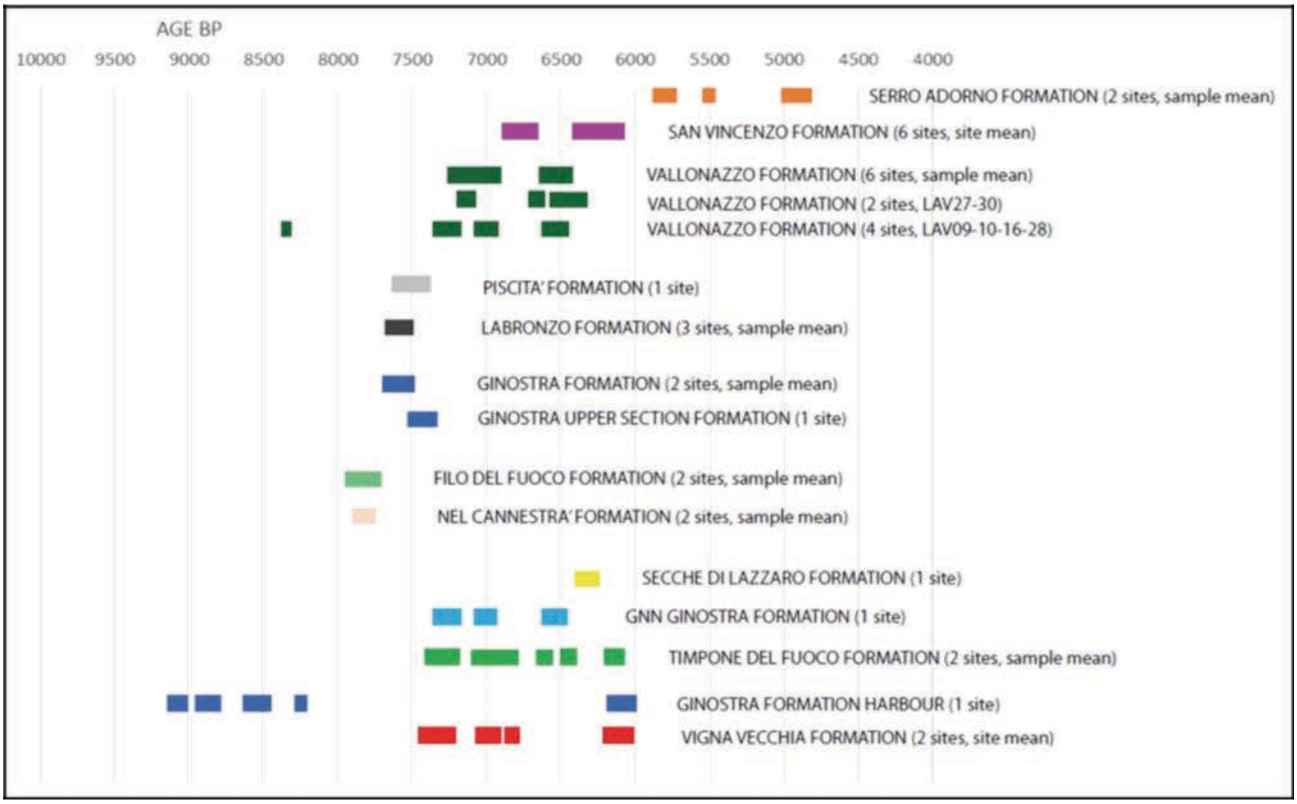

Figure 1. Paleomagnetic ages obtained from the Neostromboli sequence.

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Phase relationships of a chemically-zoned peralkaline silicic reservoir: the example of Green Tuff eruption at Pantelleria (Italy)

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Trachytes and peralkaline rhyolites (i.e pantellerite and comendite) usually represent the felsic end-member in continental rift systems and oceanic island settings. In this study we present the results of phase equilibrium experiments performed on representative peralkaline rhyolite (pantellerite) and metaluminous trachytes of the Green Tuff eruptions of Pantelleria, the sole known compositionally zoned ignimbrite at this volcanic location, which varies from a crystal-poor pantellerite at the base towards a crystal-rich trachyte at the top of the eruptive sequence. Crystallization experiments were performed in the temperature range 750-950°C, pressure 1-1.5 kbar, fluid saturation conditions with XH_2O (=H_2O/H_2O+CO_2) between 0 and 1 and redox conditions fixed around the FMQ (Fayalite-Magnetite- Quartz) buffer.

Results show that at 900 °C pantelleritic starting compositions are well above their liquidus, regardless their water content. At T < 800°C clinopyroxene is the liquidus phase followed by amphibole and alkali feldspar. Aenigmatite and quartz crystallize at 750°C and XH_2O lower than 0.8. In contrast, the trachytic composition at 800°C is highly crystallized regardless its water content. The liquidus phase is clinopyroxene crystallizing at 950°C and XH_2O<0.8 followed by iron-rich olivine and alkali feldspar. Iron-bearing minerals record the effect of both H_2O and fO_2, showing progressive iron enrichment when XH_2O decreases. Alkali feldspar becomes the most abundant mineral phase for XH_2O<0.8 at 900°C or XH_2O<1 at 850°C both at 1 and 1.5 kbar. Experiments reproduced the mineral assemblages of the natural rocks, i.e. the pre-eruptive conditions were constrained at P ~ 1 kbar, and is found that the compositional zoning in magma chamber (pantellerite to trachyte) is related to a temperature gradient (750°C-900°) within the reservoir. Moreover, our results allow demonstrating that a peralkaline liquid derivate can be produced from a metaluminous trachyte at T< 850°C after extensive alkali feldspar crystallization (~ 80 wt%).

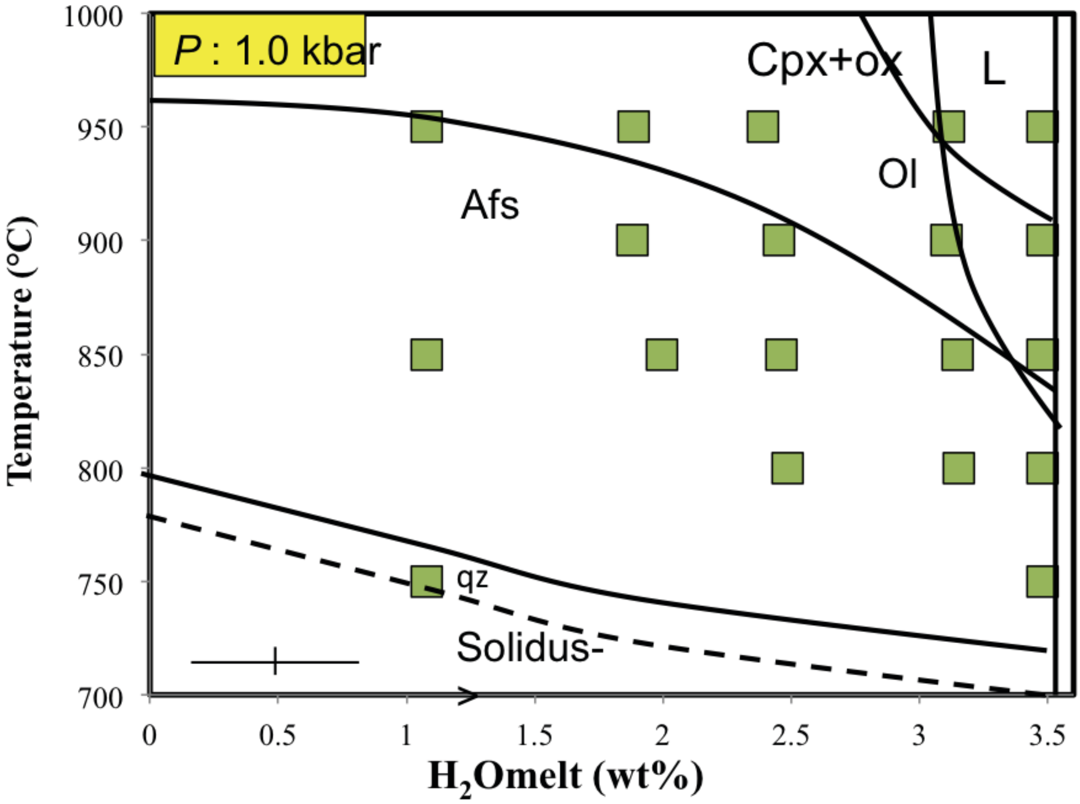

Figure 1. Phase relationships of the Green Tuff trachyte in T-H_2Omelt projections.

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A melt inclusion study of mafic to felsic tephra at Ustica Island, southern Tyrrhenian Sea

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Ustica is a Quaternary volcanic island located in the southern Tyrrhenian Sea. The subaerial portion is part 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).

During this rather large lifespan were erupted mostly mafic and subordinate trachytic magmas. Among the explosive eruptions, basaltic pyroclastic surge deposits are recurrent throughout the volcanological history of Ustica (occurred at least during 4 different ages) among them, (i) the widespread Pozzo Lapillo deposit in the central part of the island and (ii) the Falconiera tuff-cone in the northwest sector of Ustica. Trachytic tephra were erupted only during the most energetic event the Grotta Lapillo pumice fallout (sub-plinian eruption at most).

These eruptive units are poorly known from the petrological viewpoint and data on volatiles in melt inclusion are lacking. With the aim to fill this gap we carried out a study of melt inclusions (MI) hosted in olivine, plagioclase, alkali feldspar and amphibole phenocrysts, in order to determine H_2O and CO_2 concentrations by FT-IR spectroscopy as well as Cl, F, S concentrations by electron microprobe.

In the mafic products (i.e. Pozzo Lapillo, Falconiera surge deposits and Monte Guardia dei Turchi spatter-cone) olivine phenocryst compositions range from Fo88-72, plagioclase is An 65-72. In trachytic tephra, olivine, alkali feldspar and plagioclase phenocryst compositions range from Fo60-48 and Or33 Ab65,An30-60, respectively.

Major element compositions of MIs range from 46 to 63 wt.% SiO_2 and Na_2O+K_2O = 4 - 10 wt.%. H_2O concentrations in melt inclusions range between 0.5 and 2.6 wt.%, while CO_2 concentration is generally below the detection limit (50 ppm) of the FT-IR spectrometer, but in the mafic products a CO_2 concentration up to 600 ppm has been determined.

The volatile abundances in melt inclusions allowed to infer the melt inclusion entrapment pressures that resulted surprisingly low, in the range 200 - 500 bars. Although further data (e.g. halogens in MIs) are needed to rule out the possibility of post-entrapment H_2O-loss from MI, in the assumption that the highest volatile contents reflect the original H_2O melt, these data allow to locate a minimum depth for the pre-eruptive magma storage conditions as follows:

- Falconiera tuff-cone deposits: 1.0 km
- Pozzo Lapillo surge deposits: 0.6 km
- Grotta Lapillo pumice fall-out: 1.8 km
- Monte Guardia dei Turchi spatter-cone: 4.2 km

These data represent the first results from Ustica volcanic rocks, thus permit to add some elements in order to constrain the plumbing system of some key eruptions of Ustica volcanic complex and possibly its variation with time.

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Petrographic features of Tertiary volcanic products used for Neolithic human settlements in Logudoro region (Northern Sardinia, Italy)

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Since prehistoric time, the architecture of the human settlements has been deeply influenced by the lithologies occurring on their territory and, above all, by their physico-mechanical features. Among the most important archeological sites in Sardinia are the hypogean necropolises, called Domus de Janas (Home of the Witches), in Sardinian language. These artificial caves, which date back to the Neolithic Age (4000–2400 BP), are rock-cut tombs constituted by a sequence of underground chambers often decorated by sculptures, paintings and engravings.

Domus de Janas have been discovered in several outcrops within volcanoclastites related to the Tertiary parossistic manifestations of calc-alkaline magmatism (Oligo-Miocene, 32-14 Ma). The volcanic products of this cycle crop out along the Tertiary Rift of Sardinia that crosses the Western part of the island from South (Cagliari) to North (Sassari-Porto Torres). This acid volcanism is linked to the Cenozoic geodynamic evolution of the western Mediterranean.

In this work, the minero-petrographic features of the volcanoclastic suite in the Logudoro region (Northern Sardinia) are investigated with the aim to characterize the stones where these prehistoric underground structures were carved. In the study area, the landscape is characterised by volcanic plateaux some hundreds of metres thick and north-westward dipping, overlying a Paleozoic basement complex composed of metamorphic and granite rocks. The volcanoclastic succession, Aquitanian to Burdigalian in age, is composed of a sequence of dacitic to rhyolitic lava flows, ignimbrites and pyroclastic tuffs in which two ignimbrite episodes with different degrees of welding and separated by an epiclastic layers have been identified. The upper volcanic unit is overlaid by a transgressive conglomerate which marks the end of this magmatic cycle and the base of the Miocene marine succession.

From a petrographic point of view these ignimbrites are defined as rhyolites, rhyodacites and dacites composition ranging from reddish and brown in color. They generally show an eutaxitic glassy texture, sometimes with collapsed scoriae along with lithic clasts often occur. Some autigenic phases, such as clinoptilolite associated with opal-CT and smectite, derive from the transformation of precursor rhyolitic glass with a post-deposition zeolitizzation process. The secondary mineralization was favored by hydrothermal fluids preferentially circulating through fault system.

As expected, the analysis of the tombs host rock has concurred to recognize that the graves were carved in the most workability lithotypes represented by unwelded pyroclastic flow, likely exploiting previous natural erosional voids. These results also provide a petrographic background to define the state of conservation of these Neolithic monuments and to investigate the weathering and restoration of their decorations.

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The eruptions and the history of the exploitation of geothermal resources at Campi Flegrei and Ischia

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Ischia Island and Campi Flegrei are located on a NE-SW trending, volcanic ridge west of the city of Naples, Italy.

The volcanic activity range between 150 ka and the present. The last eruption at Ischia occurred in 1302 CE, and that in Campi Flegrei in 1538. Eruptions at Ischia were more frequent during Greek and Roman times, whereas Campi Flegrei was more active between 5000 and 3000 aBP.

The frequent eruptions in antiquity prevented a widespread use of geothermal resources at Ischia during Roman times. Emperor Augustus exchanged the island with Capri and returned it to the Neapolitans because of its volcanic activity, earthquakes and landslides. Campi Flegrei were instead strongly exploited by the romans because of the abundance of thermal springs. Numerous thermal baths were built all over the area and the city of Baia became renown both for the imperial palace and for its lavish "termae" that attracted the roman aristocracy as recalled by the poet Propertius.

The use of thermal baths continued during the middle age and balneo-therapy became a popular remedy that rivalled with the activity of the Salerno school of medicine.

All this activity came to an end with the eruption of Monte Nuovo in 1538, that, although of modest magnitude, caused a strong commotion and altered the state of springs for long times. The hospital of Tripergole and at least ten thermal baths were directly destroyed by the eruption and the use of the others suffered a drastic reduction. The Spanish vice-king Pietro d'Aragona in 1667, commissioned to his physician Sebastiano Bartolo, a study to identify and asses the state of the thermal baths of Campi Flegrei. Unfortunately, the cost of restoration was too high to allow a total recovering of all the baths. The list of all the termae was engraved in three marble epigraphs, two of which are still preserved in Naples and Pozzuoli. The third was stolen in 1800 by English mariners and what still remain is the name of the place "Punta dell'Epitaffio" near Baia.

Soon after the eruption of Montenuovo, a calabrian physician, Giulio Iasolino, wrote a treatise named "*De Rimedi Naturali che sono nell'Isola di Pithecusa; hoggi detta Ischia"* (1588), enumerating the springs of Ischia and describing their curative properties. Since then, the thermal springs of Ischia slowly became renown firstly in the kingdom of Naples and subsequently in Italy.

At the beginning of 1600 the curative properties of the waters prompted the building in the city of Casamicciola of a hospital for the poor, named "*Pio Monte della Misericordia*" which became the largest SPA of Europe. The edifice located Casamicciola, was destroyed by the earthquakes of 1881 e 1883, subsequently restored, is now in disuse.

The thermal springs and SPA are presently the major resource of the island.

Volcanic activity has strongly influenced the exploitation of the geothermal resources and the fears of possible eruptions has affected for long time the attitude of people against the benefits resulting from it.

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Human settlements at Ustica since Neolithic time

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Ustica was inhabited starting from Neolithic Age, as it is shown by the few fragments of ceramics with engraved or impressed decoration or with a red monochrome surface (Diana Style), recovered in recent years in a small area called Spalmatore. The tipology of these minute sherds, plausibly dating since the 6th – 5th millennium BC, makes it possible to hypothesize an origin from the area of Palermo for the first inhabitants of the island.

A Middle Aeneolithic village seems to have stood in the southeastern part of the Island, in the Piano Cardoni area, as it is shown by a few fragments of impasto ceramics and products of lithic industry picked up on the surface.

During the ancient Bronze Age the summit of Colunnella (a sort of terrace on Mt Guardia dei Turchi) was probably occupied by huts, now only hinted at by the presence on the ground of fragments of vessels of the Capo Graziano Style.

More intense was the occupation of the island in the Middle Bronze Age, between the 14th and 13th centuries BC, a period in which Ustica was probably inserted in the lively Tyrrhenian commercial routes that affected the northern coast of Sicily and the Aeolian islands. Regarding that period there are many traces of settlements documented through the surface scattering of typical pottery in the north-eastern area (Punta dell'Omo Morto and Case Vecchie); in the south-western (Spalmatore); and inside some caves (Grotta dell'Omo Morto, Grotta di San Francesco and Grotta Azzurra). It is also possible that there were small nuclei of populations in Contrada San Paolo and Piano Cardoni.

The most significant evidence of the Middle Bronze Age is the Faraglioni Village that is located in the Tramontana area on a high ridge overlooking the sea. The village had a short life between 1400 and 1250 BC. The sudden disappearance of the hut village marked a period of abandonment of Ustica, interrupted only by sporadic frequentation.

No nucleus of people settled there stably until the 3rd century BC, in the Hellenist and Roman Ages, as testified by some necropolises mainly located on the western slopes of Falconiera.

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Paleomagnetic dating of historical and prehistorical eruptions of Ischia (Italy): a tool to answer open chronostratigraphic questions

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The island of Ischia, in the Gulf of Naples, is the emergent peak of a volcano that dates back to more than 150 ka ago. From Neolithic times onwards it has experienced a complex history of human colonization alternating with volcanic eruptions that destroyed settlements and drove away the population. Recent volcanological research and archaeological excavations have demonstrated that volcanism has been intense during the period in which civilization began to gain ground.

Volcanism was mainly concentrated in the past 2.9 ka, when at least 34 effusive and explosive eruptions followed one another with very short periods of interval. Only few eruptions were strong enough to produce widely dispersed deposits, useful as marker beds. Although archaeological findings helped to define the age of some eruptions, in many cases the correlations are problematic, due to the limited areal extent of the eruptions deposits.

Absolute age determination of very young deposits poses problems and questions that the paleomagnetic dating method could answer. In fact, paleomagnetism can be applied on whole rock samples and does not require a given petrographic composition, as nearly all volcanics contain ferromagnetic grains yielding a strong remanent magnetization. Dating is achieved by comparing paleomagnetic directions retrieved from volcanics to reference curves showing the local directional variation of the (paleo) secular variation (PSV) of the geomagnetic field. Such curves have been continuously implemented in the last years, and nowadays a well-constrained reference curve –at least for Europe - is available for the last 14 ka. As the geomagnetic field directions changes rather quickly (up to ca. 7° per 100 years during the Holocene in the Mediterranean domain), paleomagnetism may date volcanics with an accuracy of 100-200 years, in the most favorable cases. In the last 15 years, paleomagnetism has been used successfully to date Holocene volcanics from many Italian active volcanoes, such as Vesuvius, Etna, Stromboli, Vulcano, Lipari, and Pantelleria.

In order to answer open questions on Holocene volcanic chronology at Ischia, a new paleomagnetic sampling has been carried out, mostly on those unit whose chronostratigraphic position was poorly constrained. Nine new paleomagnetic sites were sampled and the cores were oriented in situ by both a magnetic and a sun compass. Each core was demagnetized in at least ten steps by alternating field (up to a 150 mT field) or thermally (up to 680°C), and the remanent magnetization was measured after each step by a 2G DC-SQUID cryogenic magnetometer. Dating was obtained by comparing site-mean paleomagnetic directions with the Sha.Dif.14k PSV reference curve.

Moreover, we also re-dated the paleomagnetic directions already available in the literature with the new curve.

The interpretation of the obtained age results is in progress, as for some units several age windows are possible, and the best age has to be chosen considering the available stratigraphic, historical and radiometric evidence. As a preliminary conclusion, it seems that the new ages fit reasonably well with the stratigraphic framework reconstructed till now and yield new constraints to improve the geochronological and archaeological evidence available from the literature.

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Geochemical evidences of increasing magmatic gas input before the seismic swarm apex of the 2011-12 volcanic unrest of Santorini, Greece

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On January 2011 an anomalous seismicity (ML≤3.2) began inside the Santorini caldera on the active volcano-seismic Kameni line. In the same time, a rapidly expanding radial deformation was observed from a Mogi source located within the caldera to the north of Nea Kameni (NK), the volcanic islet where six eruptions have occurred from 1570 to 1950. This seismic and geodetic unrest, unprecedented at Santorini at least since the 1950 eruption, was possibly related to the inflation of a magmatic source which might have led to a volcanic reactivation. Volcanic unrests are characterized by an anomalous increase of CO_2 diffuse soil degassing reflecting an increasing gas release from relatively shallow magma bodies (e.g. Vulcano and Stromboli).

In early January 2012, we established a target area (TA) on the most degassing zone of NK with 115 points over 46,000 m2, for periodic repetition of CO_2 flux measurements by accumulation chamber. Tarchini et al. found a CO_2 flux per unit surface nearly double of the maximum pre-unrest value found by Chiodini in their 1994-1995 surveys, with a corresponding increase of the maximum flux value from 9000 to 22,000 g/m2day. We estimated a total CO_2 flux of 39.9 ton/day from the TA.

Mid January 2012: the highest number of daily seismic events was recorded within a seismic swarm begun at the end of September 2011.

Late January 2012, Parks et al. measured a CO_2 emission of 38±6 ton/day from a similar area.

We carried out five new surveys on the target area from May ‘12 to June ‘13, finding a progressive decrease of the total CO_2 soil flux to pre-unrest values. Contemporarily, the same decrease pattern was measured from a target area in Firà on Thera Island, suggesting that a long segment of the Kameni line was pervious to magmatic/hydrothermal gases during the unrest.

A marked decrease of the intracaldera seismic activity accompanied this decrease of CO_2 soil flux from NK and Firà, supporting the hypothesis that a small batch of more basic volatile-rich magma had intruded into the shallower and more evolved plumbing system as also inferred by Parks et al. and Rizzo et al.

Data suggest that the 2011 Santorini unrest started vanishing since May 2012.

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Basaltic Magmatism in the Sicily Channel

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The Sicily Channel, situated on the continental shelf between Sicily and north Africa, has been affected by basaltic volcanism from the Miocene (Tortnian) to the Holocene and as recently as the 19th century (1831, 1867, and 1891 CE.) This volcanism has resulted in the formation of numerous seamounts (including the short-lived island of Ferdinandea) and two islands, Linosa and Pantelleria. These volcanoes are located along the margins of two northwest-southeast trending transtensional rift basins ("troughs"), and are the result of adiabatic decompression melting of a lithologically heterogeneous asthenosphere beneath the Sicily Channel region.

Linosa is a small (~6 km^2) island that consists entirely of Na-alkaline mafic lavas and tuffs that erupted in three stages at 1070 ka, 700 ka, and 530 ka and created several coalescing cinder cone and maar volcanoes. Relatively primitive (MgO > 9 wt%) basaltic lavas occur on Linosa, which makes it an ideal setting to investigate the nature of the mantle and conditions of partial melting of the mantle in the Sicily Channel. We present and compare the results from four commonly used methods: (1) Estimation of the composition of primary magmas by iteratively "correcting" it for olivine fractionation until the recalculated basalt has an Mg# that has been experimental determined to be in equilibrium with mantle peridotite with an olivine composition of ~Fo_{90}, followed by calculation of the average temperature and pressure of magma segregation; (2) Application of various trace- and major-element ratios that purport to identify the composition of the source of the magmas; (3) Rare-earth element inverse modelling using the INVMEL program to calculate melt curves to determine the degree of partial melting as well as the bottom and top of the melting column; and (4) Application of the pMELTS model to determine the conditions of isentropic partial melting for a variety of source compositions and potential temperatures over a similar range of pressures (3 GPa, the lower limit of pMELTS capability to 1.8 GPa), corresponding to the base of a ~60 km lithosphere. Preliminary results suggest that major- and trace-element ratios alone provide contradictory results. Results from the two inverse modelling techniques are consistent with each other, and suggest that magmatism at Linosa resulted from 2.0-2.5% partial melting of a lherzolite source consisting of small amounts of recycled basalt mixed with depleted MORB mantle with a melting column extending from ~100 to 60 km (primarily in the spinel-garnet transition zone) with mantle potential temperatures of ~1425°C. The island of Pantelleria lies ~120 km to the northwest of Linosa. It is by far the larger (~83 km^2) of the two islands and represents the emergent portion of a volcanic edifice that rises 836 m above sea level and about 2200 m above the sea floor within the Pantelleria graben. Most rocks exposed on the island are felsic (trachyte-panellerite) and younger than the 45.7 ± 1.0 ka pantelleritic Green Tuff, the caldera-forming ignimbrite of the Cinque Denti caldera. The oldest exposed pantelleritic lava on the island has been dated at dated at 324 ± 11 ka, but most of the island is submerged, much older, and most likely primarily basaltic. The oldest documented basalts (~80-120 ka) are exposed primarily in outcrops along the coast and along the scarp of the Cinque Denti caldera. Younger mafic lavas are found only in the northwestern part of the island and include flows that erupted at ~29 ka from the Cuddie Bruciata, Ferle, and del Monte cinder cones, and at ~10 ka from the Cuddie Rosse cinder cone. The most recent volcanic activity occurred ~4 km NW of the island at the submarine (~250 m b.s.l.) Foerstner volcano on October 17, 1891 C.E. Pantelleria basalts are characterized by more radiogenic lead isotope ratios and major- and trace-element signatures that strongly suggest they are derived from depleted mantle with a much greater contribution from recycled basalt than Linosa.

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Cascading effects and cumulative impacts of volcanic eruptions: simulation model and decision support tool application in Santorini

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Cascading effects triggered by natural or anthropogenic hazards are recently emerging as a key topic in the field of risk assessment, disaster risk reduction and emergency management. Only a limited number of studies focuses on the complex is sues of cascading effects modelling, and robust methods and tools to quantify the potential impact on the elements at risk (people, buildings, critical infrastructures, economy, environment, etc.) are available in literature and further researchers are still needed.

Generally, sequences of events (e. g. an earthquake triggering a landslide which in turns triggers a power outage) can involve the same element at risk and the combined effects of cascading phenomena can strongly amplify the impact caused by single events in terms of extension of the impacted area and damage levels. The final impact on territory can be very important and its underestimation could result in a failure management and emergency planning strategies in place.

This presentation discusses from a theoretical point of view the modelling needs and main issues to be taken into account in the development of cascading effects simulation tools aimed at effectively support decision-makers in their preparedness and disaster mitigation strategies, in the framework of emergency planning at local, national and international level.

The theoretical model here proposed defines a methodological framework to address hazard/impact assessments of cascading effect scenarios based on the understanding of dependencies and interactions between different hazards and the influence of exposure and vulnerability of the elements at risk on the base of the cumulative damage due to the sequence of events, both from damage propagation across service networks and critical infrastructures.

The model has been developed in EU-FP7 project SnowBall (Lower the impact o f aggravating factors in crisis situations thanks to adaptive foresight and decision-support tools, 2015-2017).

It is based on the refinement of a consolidated methodology built-up in previous and ongoing research projects, where LUPT-PLINIVS play ed a key role in the problem conceptualization and software modelling implementation.

Within Snowball project, the reference pilot application concerned the simulation of the potential cascading effects triggered by a reactivation of the Nea Kameni volcano in Santorini island. Based on the potential hazard scenarios define d with the support of local and international experts (volcanologists, seismologists, geologists, critical infrastructure managers, etc.) different Time Histories have been analysed (TH1. Volcanic-Unrest - No Eruption; TH2. Volcanic-Unrest - Vulcanian Eruption; and TH3. Volcanic-Unrest - Sub Plinian Eruption) and the consequent cascading effects chains and cumulative impacts quantified.

The implementation of the theoretical model within the Cascading Effects Impact Simulation tool allow to provide decision makers with actionable information derived from the different features available, such as the triggering event/time history b rowser, the quantification of impacts on each element at risk in each timestamp along the event's timeline, the map/table comparison of alternative impact scenarios, and the preparedness measures (short- and long-term) module to evaluate the cost and benefits of alternative options through a user-defined multi-criteria analysis.

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Impact of explosive volcanic eruptions: a dynamic simulation assessment model for Vesuvius and Campi Flegrei

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The effects of a volcanic eruption on the built environment have been investigated in the last 15 years, defining a comprehensive framework of studies, surveys, and simulations that include all the different eruptive phenomena and their possible impacts on existing buildings and infrastructure. Nevertheless, to define effective Disaster Risk Reduction, emergency planning and management strategies in volcanic high risk-prone areas – such as the Campania Region – a broader approach is needed. In fact, a basic consideration is that the cumulative effects given by a complex eruptION produce extremely variable impacts on constructions. Thus, the effects depend on the specific time history of the event, on the building typologies, and on their level of vulnerability.

This specific approach has been recently formalized to evaluate the impact of a su b-Plinian eruption in the Vesuvius and Campi Flegrei area through the development of a numerical model for the definition of impact scenarios. A dynamic model able to evaluate the cumulative damage distribution in time and space developed within several national and international projects such as Exploris (Explosive eruption risk and decision support for EU populations threatened by volcanoes, EU-FP6-proj. ref. EVR1CT-2002-40026) and SPeeD (Hazard and Damage Scenarios for Campania Region Volcanoes 200 7-2009). The eruptive phenomena considered include earthquakes, ash fall, pyroclastic flow, and lahars, and their impact on relevant elements at risk, such as population, buildings, critical infrastructures, transport networks and economy is assessed through dynamic scenarios. The basic assumption is that the impact damage due to a volcanic eruption depends on several disastrous events whose effects are cumulated in the final scenario. The damage level along the eruptive history is strictly linked to the number of events, their range of intensity, and the distribution in time and space.

The PLINIVS Volcanic Impact Simulation Model is a tool available to the Italian National Department of Civil Protection to quantify the potential losses consequent to a possible eruption of Vesuvius or Campi Flegrei. The results are strongly dependent on the hypothesis assumed and on the parameters used as inputs, providing impact scenarios with a probabilistic estimation and uncertainty treatment. The results allow emergency planners and decision makers to assess with a great level of detail the resources needed to improve the preparedness measure s needed to face the event and to implementat technically feasible and cost-effective mitigation measures on buildings and infrastructure to reduce the expected damage, such as the seismic retrofitting of vulnerable buildings along the escape routes identified in the evacuation plan, which might fail due to the presence of debris from collapsed buildings which can affect the practicability of roads.

The presentation will focus on the concept and methodology developed to build the Simulation Model and will illustrate relevant applications performed by PLINIVS Study Centre of University of Naples Federico II as Centre of Competence of the Italian National Department of Civil Protection for volcanic risk, used for the preparation and updating of the emergency plan for Vesuvius and Campi Flegrei are as.

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