PROJECT V3

Sub-Project V3_3 – Ischia

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Coordinators:

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State of the Art

The island of Ischia is the emerged top of a large volcanic complex rising more than 1,000 m above sea floor at the north-western corner of the Gulf of Naples. It is an active volcanic field composed of volcanic rocks, landslide deposits, and subordinate terrigenous sediments, reflecting a complex history of alternating constructive and destructive phases due to an interplay among tectonism, volcanism, volcano-tectonism, erosion and sedimentation. The volcanic system is still active, as testified by the intense volcanism in historical times, widespread fumaroles and thermal springs, and by seismic activity. Volcanism at Ischia began prior to 150 ka B.P. and continued, with centuries to millennia of quiescence, until the last eruption occurred in 1302 A.D. Recent studies have demonstrated that during the time interval between 74 and 55 ka B.P. there was a dramatic change in the structural setting of both magmatic system and volcanic edifice. This time interval, previously regarded as a mainly quiescent period, bore witness to a complex volcanic activity with the largest eruptions recorded on the island. This period culminated with the caldera-forming Mt. Epomeo Green Tuff eruption (55 ka) which was followed by block resurgence of the caldera floor, at least since 33 ka. Resurgence dynamics influenced the later volcanic activity determining the conditions for magma ascent mainly within the eastern portion of the island and along pre-existing regional faults. During the last period of activity, started 10 ka B.P., volcanism was mainly concentrated around 5 ka and in the past 2.9 ka. In the past 5 ka, reactivation of faults and related volcanic activity, are accompanied by emplacement of deposits generated by surface gravitational movements. These deposits preceded and followed the emplacement of volcanic rocks, testifying that slope instability conditions were induced by reactivation of vertical movements, which also generated faults and fractures through which volcanism was fed. Furthermore, the availability of large amount of loose material, rapidly accumulated along the slopes during eruptions, predisposed the conditions for landslide generation.

Volcanic hazards assessment and long-term forecasting of a future eruption at Ischia have to be the prime objectives of future researches on the island. Although variable researches have been carried out on the island in the last decades, they have never been finalised to volcanic hazards assessment. Therefore it is necessary to formulate a multidisciplinary and coordinated project with the aim of finalising the available data and filling the knowledge gaps. Still a large amount of information necessary for formulating a comprehensive hypothesis on the behaviour of the volcano and its magmatic feeding system, is lacking. The structure of the volcano and its underlying lithosphere needs to be better defined through combination of structural and geophysical data. As only one third of the volcano is above sea level, data from marine geology and geophysical investigations are needed. This is true also for the definition of the geomorphic characteristics of the entire volcano. According to the present knowledge, the portion of the volcanic and deformation history of the system, most useful for volcanic hazards assessment, is related to the past 10 ka. But, as previously mentioned, the knowledge of the intense volcanism and deformation (74 - 55 ka),

which has likely affected the later behaviour of the volcanic system, is quite poor. Therefore, in order to understand the present state of the volcano, it is necessary to investigate its volcanic, magmatic and deformation history over the past 74 ka. Through these investigations, the sequence of events and its timing should be defined. The behaviour and structure of the magmatic system should be assessed as well, also in terms of physical and chemical parameters, rheological properties and glass structure. The diffuse occurrence of hot-water springs and fumaroles testifies the existence of active geothermal and hydrothermal systems. Investigation of these systems and definition of their physico-chemical characteristics are important pieces of information for hazards assessment. Another hazard on the island, closely related to volcanism, is the occurrence of surface gravitational movements which generate landslides deposits at variable scale. This implies that investigations need to be carried out also on these deposits, in order to have a more complete picture of the geological hazards on the island. Landslides could also generate tsunamis which would effect all the coast of the Neapolitan area. Such a possibility has to be investigated in order to define the likely effects. The present knowledge of Ischia eruption precursors is very poor. Therefore, in order to construct a dataset necessary for a future definition of the alert levels, it is useful to collect geological, historical and archaeological data on the precursors of the Ischia eruptions.

Description of the Activities

The project is organized in 5 Tasks, each entrusted to a scientific responsible, grouped in 2 Research Lines devoted to a) the definition of the present state, b) the definition of the eruptive scenarios and related probability, and quantitative estimate of the volcanic hazard. The specific Tasks are devoted to: 1) the definition of the structural and geomorphological evolution and preset setting; 2) the reconstruction of the volcanological history, with particular reference to the past 74 ka; 3) the definition of the evolution, structure and present state of the magmatic feeding system; 4) the characterization of the groundwater and geothermal systems; 5) the assessment of volcanic and landslide hazards.

Each RU will work in coordination with the others and in particular with those involved in the same task. The coordinator of the project and the scientists responsible of each task will encourage coordination among RUs. An annual meeting of all RUs will be held and meetings of RUs of one or more tasks will be encouraged.

Research Line 1. Definition of the present state of Ischia Island

Task 1. Structure and geomorphology.

UR Coordinating: de Vita (INGV-OV)
URs Participating: Rapolla (Univ. Napoli), De Alteriis (CNR-IAMC), Capuano (Univ. Molise)

Task 1 includes structural, geophysical, stratigraphical, sedimentological and geomorphological studies aimed at: a) defining the structural setting of both emerged and submerged portions of the Ischia volcano and of its underlying lithosphere; b) defining the relationships among tectonic and volcano-tectonic deformational features, location of volcanic vents and slope instability; c) reconstructing the stratigraphic sequence of landslide deposits and defining their physical characteristics, transport and depositional mechanisms.

The structure of the emerged part of the island will be investigated by carrying out a field survey of the macroscopic and mesoscopic deformational features. The structural data will be statistically analysed in order to define the related stress field. A geological survey will be carried out in order to: a) define the relationships among tectonic and volcano-tectonic deformational features, location of volcanic vents and slope instability; b) reconstruct the stratigraphic sequence of landslide

deposits and define their physical characteristics, transport and depositional mechanisms. Absolute age determinations will be performed in coordination with Task 2. A quantitative geomorphic analysis will be performed in order to better constrain the landscape modifications and to extract structural and volcanological features. Both conventional photo interpretation and automatic feature recognition and classification approaches will be used in the analysis and interpretation of a high spatial resolution DTM in GIS environment. Thermo-mechanical modelling will be performed to simulate the intrusion of magma into the crust and analyse the surface deformation under different tectonic regimes and pre-existing fault structures. The submerged part will be investigated through: a) interpretation of the existing DTM; b) advanced boundary analysis of the magnetic field; c) matching the morphobathimetry with seismic data and volcanological and structural framework; d) sedimentological and geochemical analysis of available rock samples. The deep structure will be investigated through: a) development and implementation of innovative techniques of analysis and interpretation of active/passive seismic data recorded during Serapis project and already available gravity data; b) reinterpretation and partial processing of OGS digital data, acquired in the Naples Bay offshore during the 1973 and the offshore M-30 and M-36 CROP lines; c) acquisition and interpretation of a new aeromagnetic dataset; d) definition of the spatial distribution of radioactivity, by the use of a helicopter-borne gamma ray spectrometer device; e) self potential survey and 3D tomographic inversion of the related data.

Task 2. Volcanology and geochronology

UR Coordinating: Orsi (INGV-OV)
URs Participating: Guillou (LSCE-CEA), Sprovieri (CNR-IAMC)

This task includes stratigraphical, volcanological, geochronological, geophysical, historical and archaeological investigations aimed at filling the gaps of knowledge on the volcanic history of Ischia over the past 74 ka and to produce data essential to volcanic hazards assessment. In particular, the stratigraphic sequences of the volcanic deposits aged between 74 and 50 ka and younger than 10 ka will be reconstructed. Investigation of the 74-50 period is important in order to constrain the mechanisms that resulted in modification of the volcanic system and evaluate their effects on the subsequent activity. Key deposits in the volcanic sequences will be dated by $^{40}Ar/^{39}Ar$ and AMS ^{14}C methods, in order to constrain the timing of the volcanism. Samples to be dated will be selected in cooperation with other Tasks of the project in order to constrain also the deformation and gravitational movement events, and the timing of the magmatic processes. For each recognised deposit, the spatial distribution and the sedimentological, stratimetrical, structural and textural features will be defined. Components analyses will be performed on fallout deposits in order to collect data useful for both understanding the character of the explosions and modelling the eruption columns. For these deposits, isopachs and isopleths maps will be also constructed. In addition to thickness, also the density of variable types of fallout deposits will be measured in order to define their load on the ground. The distal ash deposits of the Ischia explosive eruptions will be investigated through the analysis of the 33-meters long MD01-2473 core, recovered in the Tyrrhenien Sea, about 50 km N of Stromboli. All these data will allow to: a) locate the vent/vent area, b) evaluate the volume of erupted magmas through a computer assisted (GIS-based) method, c) estimate the eruption dynamics, d) define the transport mechanisms for all eruptions, and e) estimate the magnitude and intensity of the explosive eruptions. They will also allow to construct areal distribution and frequency maps for lava flows and domes, and fallout and pyroclastic current deposits, as well as frequency maps for load on the ground by fallout deposits. Integrating the data collected within the activities of this Task and Task 1, a chronogram of the volcanic, deformation and gravitational-movement events will be constructed.

To identify eruption precursors and the ground deformation background level also archaeological researches and historical documents analyses will be carried out. All these

investigations will permit to evaluate the effects of eruption precursors such as ground movements, fracturing and faulting on manufacts. Reinterpretation of DInSAR Satellite Interferometry data collected since 1992, and levelling data acquired since 1984, will allow definition of the ground deformation background level.

Task 3 Evolution, structure and present state of the magmatic feeding system

UR Coordinating: Sbrana (Univ. Pisa)
URs Participating: D'Antonio M. (Univ. Napoli), Petrini (Univ. Trieste),Tonarini (CNR Pisa)

Task 3 will be devoted to petrological investigations on volcanic rocks representative of the 74-55 ka and of the past 10 ka periods of activity, aimed at the definition of the behaviour of the magma feeding system through time and its present state. In order to achieve this goal, petrological data will be acquired through many different analytical techniques on whole-rocks, separated minerals and glasses from volcanic rocks representative of the selected periods of activity, sampled in cooperation with RUs Orsi and de Vita.

Petrographic, mineralogical, geochemical and isotopical (Sr, Nd, Pb, O and B) investigations will be carried out on bulk rocks, groundmasses and separated minerals. Whole-rock major and trace element analyses will be performed by ICP-AES and ICP-MS techniques. The major oxide analyses of minerals and glass will be performed by EDS-WDS electron microprobe techniques. The isotopic analyses will be performed by thermal ionisation mass spectrometry techniques. The data will be interpreted in order to identify the geochemical characteristics of the magmas inherited from the mantle source, and to define the magma evolution processes occurring in deep and shallow reservoirs.

Solid-state nuclear magnetic resonance spectroscopy investigations will be applied to the study of silicon site speciation in the network structure of volcanic glasses, with the aim of identifying and quantifying the hydrous environments, in order to determine the distribution of molecular water in the glass. The study of hydrous species and CO_2 abundance and the mapping at a few micron scale in glasses and fluid inclusions will be attempted by using an infrared synchrotron radiation source. The structure of glasses and the structural characteristics of hydrous species will be related to the glass chemistry and surface analysis. The nature of solutes in aqueous components will be investigated by isotopic measurements.

Silicate melt inclusion investigations in phenocrysts will be carried out through optical microthermometry and microanalysis, aimed at defining PTX conditions of the Ischia magmatic feeding system. Microthermometry will determine the homogenization temperature of the inclusions, correspondent to the minimum temperature of crystallization of the host mineral and magma. Major elements, Cl and S in glasses, melt inclusions and host minerals will be analysed by EDS-WDS microanalysis. H_2O and CO_2 analyses in trapped melts will be carried out by FTIR. The volatile contents of magmas will allow assessment of crystallization and storage pressures from models of solubility for H_2O and CO_2 in silicate melts.

Geochronological determinations will be carried out through U and Th decay series disequilibria by TIMS techniques. Detailed internal isochrons will help to unravel the timescales of processes that formed the magmas feeding the 74-55 ka period of activity.

Task 4 Hydrogeological setting and geothermal system

UR Coordinating: Aiuppa (Univ. Palermo)
URs Participating: Luzio (Univ. Palermo), Sbrana (Univ. Pisa)

The diffuse surface hydrothermal manifestations on Ischia Island are clear evidences of the vigorous interaction between deep-rising magmatic/hydrothermal volatiles and shallow fluids of

meteoric and/or marine derivation. Establishing the complex spatial-temporal mixing relations between the different fluid components is a pre-requisite for the definition of a quantitative model of the groundwater/hydrothermal system. In turn, such an interpretative model is essential for predicting the potential geochemical signals accompanying an eventual future volcanic unrest on the island.

This task attempts at a multi-disciplinary and systematic characterisation of the structure and chemical-physical properties of the Ischia island groundwater/hydrothermal system, by combining: a) a hydrogeochemical survey of surface thermal manifestations; b) a geochemical, petrological and mineralogical characterisation of surface alteration facies, and c) an electrical and electromagnetic geophysical survey. Hydrogeochemical investigations will be devoted to a chemical characterisation of thermal manifestations, including the determination of major and minor (B, Li, Sr, Fe, Mn) dissolved species, trace elements (with particular reference to ore-forming elements Cu, As, Zn, Sb, Tl, Hg, ect.), and dissolved gases (CO_2, CH_4, O_2, N_2). Isotope markers (O and H isotopes of H_2O and C, B, S and He isotope composition of dissolved carbon, boron, sulphur, and helium, respectively) will be used for assessing and mapping the extent of interaction between deep-derived volatiles (either hydrothermal or magmatic) and the groundwater system, and for the reconnaissance of the relative contribution of end-member components (i.e., geothermal reservoir brines, meteoric water and seawater). This reconnaissance study will also provide the quantitative background for the selection of a few samples to focus on the analysis of temporal trends. Also, cross correlation of thermal waters compositional data with the mineralogical, geochemical and isotopic features of hydrothermal paragenesis (from analysis of deep-seated xenoliths present in the exposed pyroclastic sequences) will allow quantitative modelling of water-rock interaction processes and reconstruction of T-dependent mineral-solution equilibria. This task will also benefit from fluid and melt inclusion investigations, allowing P-T-salinity conditions of the deep seated hydrothermal reservoir(s) to be derived. The reconstruction of the vertical and lateral continuity of both the shallow-groundwater system and the deep-hydrothermal reservoir(s) will also be attempted by the use of geophysical prospecting methods (electrical vertical soundings and TEM), such methods being adequate to model the distribution of permeable and impermeable bodies.

Research line 2: Definition of eruptive scenarios and estimate of the volcanic hazard

Task 5. Volcanic and related hazards assessment

UR Coordinating: Orsi (INGV-OV)
URs Participating: de Vita (INGV-OV), de Alteriis (CNR-IAMC), Tinti (Univ. Bologna)

This task includes geological and volcanological investigations, and physical modelling and numerical simulations devoted to: a) defining the areas at variable probability of opening of a new vent; b) defining probabilities for the expected eruption scenarios; c) defining the expected surface gravitational movements at variable scale; d) physical modelling and numerical simulation of the expected volcanic events; e) constructing probability hazards maps for vent opening, lava flows and domes, tephra fallout, pyroclastic currents, and surface gravitational movements; f) assessing tsunami hazard in relation to gravitational movements.
All the data and maps produced within the activities of this Task and of the other Tasks will be statistically elaborated to produce a single probability definition of the expected eruption scenarios, and probability hazard maps for opening of a new vent, fallout and pyroclastic currents. The use of an ash transport model previously developed will permit to assess the ash loading probability for each given threshold in the areas potentially affected by fallout. Application of a probabilistic model based on the “maximum slope” will be calibrated by using information on the past effusive eruptions at Ischia and will permit both to estimate the probabilities of vent opening in different areas, and to construct a probability lava hazard map.

The variable recognized landslide deposits will be classified, their volume will be estimated and the expected gravitational movements will be defined. A probability map of occurrence of new or remobilisation of older landslides onshore-offshore will be constructed.
The ability of SAR interferometry to point out diffuse deformation at variable scale, will be used to study the surface gravitational movements of Ischia. Through this technique it is possible to evaluate amplitude and direction of the ground movements. The comparison with geodetic data will permit to discriminate the differences in coherence with neighbouring areas. In order to point out the main factors controlling the slope instability, selected areas will be related to different backscattering values, which will be referred to the intrinsic soils properties to characterize them in terms of structural and physico-chemical properties.

The dynamics of the tsunami generation by landslides will be investigated by the double model already used for the Holocene collapse of the Sciara del Fuoco and for the recent 2002 landslides at Stromboli. Improvement of this model will be considered, especially to deal with the high-mobility and large fragmentation feature of the large debris avalanche to the south of Ischia. A second approach will also be attempted and a preliminary version of a code will be built to handle the landslide mass as a second high-density fluid. Tsunami evolution in the near- as well as in the far-field will be computed, the tsunami impact along the coast of Ischia and of the Gulf of Naples will be calculated, and inundation map along these coasts will be produced.

List of deliverables

Task 1: Structure and geomorphology

Deliverables: modelling of the structural setting of the lithosphere beneath the volcano, with particular reference to location and size of the magmatic system - structural map of the volcano - stratigraphic sequence and physical characteristics database of the surface gravitational movement deposits - morphological database constructed on high spatial resolution data (DEM, DTM, Remotely Sensed Imagery) - digital thematic maps - 3D visualization - GIS database.

Task 2: Volcanology and geochronology

Deliverables: stratigraphic sequence of the exposed deposits - maps of the areal distribution of the deposits of effusive eruptions and pyroclastic currents - isopachs and isopleths maps for fallout deposits - frequency maps for lava domes and flows, and pyroclastic current and fallout deposits - frequency maps of load on the ground by fallout deposits - chronogram of the volcanic, deformation and surface gravitational movement events - maps of the active vents through time – database of the physical parameters of the volcanic eruptions – database of the geological, historical and archaeological – definition of the background level using the monitoring network data.

Task 3: Evolution, structure and present state of the magmatic feeding system

Deliverables: modelling of the mantle source characteristics of the Ischia magmas – modelling of the magma chamber processes before and during eruptions of variable magnitude and occurred in variable structural conditions – database of the physical and chemical parameters, and rheological properties of the erupted magmas – modelling of volatiles in the magmatic reservoir/s - experimental determination of glass structure and distribution of hydrous species - relations among magma structure, physical and chemical parameters, and eruption dynamics - time of growth of large magma chamber;.

Task 4: Hydrogeological setting and geothermal system

Deliverables: geochemical maps of the spatial distribution of major, minor and trace species and dissolved gases in the groundwater system - assessment of the budget of volatiles (CO_2, He) transported by the groundwater system - identification of hydrogeochemical precursors of volcanic unrests - graphical two-three dimensional representations for the geometry of the deep-seated hydrothermal reservoirs

Task 5: Volcanic and related hazards assessment

Deliverables: probability hazard map for opening of a new vent - eruption scenarios - modelling of eruption column and fallout deposits - database of the physical parameters of the expected hazardous phenomena needed for vulnerability evaluation – modelling of lava flows - probability tephra fallout hazard map - probability pyroclastic currents hazard map – probability lava flows and domes hazard map - classification and volume estimation of landslides deposits in both emerged and submerged portions - surface gravitational movements hazard map - modelling of tsunami generation and propagation - tsunami inundation maps of the island and of the Gulf of Naples.

SUB-PROJECT V3_3 – ISCHIA

TABLE MAN/MONTHS

U.R	Institutions	Principal Responsibles	Task1 Structure and geomorphology	Task2 Volcanology and geochronology	Task3 Magma feeding system	Task4 Geothermal system	Task5 Volcanic hazard	Mesi p. cofin.	Mesi p. rich.
UR-1	UniPa, INGV-PA	Aiuppa, D'Alessandro, Pecoraino				@		22	24(UniPa
UR-2	UniMol, UniNa, UniSannio	Capuano, Russo, De Matteis	@					26	
UR-3	UniNa, INGV-OV	D'Antonio, Civetta			@			12	24 (UniNa)
UR-4	INGV-OV, UniRmTre, UniRm1, UniPi	De Vita, Casero, Faccenna, Nappi	@					63	
UR-5	CNR-IAMC, UniRm1	De Alteriis	@				@	24	
UR-6	CEA-CNRS (FR), INGV-OV	Guillou, Scaillet		@				8	24 (CEA_CNRS)
UR-7	UniPa, INGV-PA	Luzio, De Luca				@		32	
UR-8	INGV-OV, UniNa, Sopr. Arch. Na, Univ. Goettingen (D), INGV-CT, UniFi, UniTri	Orsi, de Vita, Heumann, Tommasini		@			@	54	24 (assegno di ricerca INGV-OV)
UR-9	UniTri, UniPi, CNR-IPCF, UniRm1	Petrini, Forte, Lupi			@			23	12 (UniTri)
UR-10	UniNa, UniCal	Rapolla, Florio, Pece, Di Maio	@					50	
UR-11	UniPi	Sbrana, Marianelli, Fulignati			@	@		24	
UR-12	CNR-IAMC, CNR-ISMAR, INGV-OV	Sprovieri		@				40	

UR-13	UniBo	Tinti, Armigliati, Zaniboni					@	41	12 (UniBo)
UR-14	CNR-IGG	Tonarini, Dallai, Dini			@			12	
Totale								431	120

SUB-PROJECT V3_3 – ISCHIA

Table RU and related funding request

N. UR	Istituz.	Resp UR	Personale		Missioni				Consumi servizi		Inventariabile	
					Italia		Estero					
			2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
UR-1	UniPa	Aiuppa	16000	16000	4500	4000	2500	3000	9000	9000		
UR-2	UniMol	Capuano			1500	1500	1500	1500	4500	4500	1500	
UR-3	UniNa	D'Antonio	19000	19000	2000	1000		1000	3500	5000	2000	
UR-4	INGV-OV	De Vita			4500	3850		1650	2500	4000	2000	
UR-5	CNR-IAMC	De Alteriis			2000	2000	2000	1500	4000	4000		
UR-6	CEA-CNRS (FR)	Guillou	16000	16000			1000	1000	1000	1000		
UR-7	UniPa	Luzio			6000	4000			1000	1000	1500	1000
UR-8	INGV-OV	Orsi[1]			3500	4900	1500	2100	12500	14500	5000	
UR-9	UniTri	Petrini		19000	1000	1000	1000		2000	1000	2000	
UR-10	UniNa	Rapolla			1000	1000			21000	4000		
UR-11	UniPi	Sbrana			4000	4000			9000	9000		
UR-12	CNR-IAMC	Sprovieri			1250	1500	1250	1500	6000	2000		
UR-13	UniBo	Tinti	8000	8000	1250	1250	1250	1250	3000	3000	2000	1000
UR-14	CNR-IGG	Tonarini			1400	1200	600	800	5000	5000		
		TOTALE	**59000**	**78000**	**33900**	**31200**	**12600**	**15300**	**84000**	**67000**	**16000**	**2000**
GRAN TOTALE: 399000												

[1]8000 euros (4000 per year) included under the voice "Consumi e servizi" will be provided to Univ. of Goettingen (D) for research activities under the responsibility of A. Heumann.