PROJECT V3

Sub-Project V3_7 – Pantelleria

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Coordinators:

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State of the Art

The island of Pantelleria represents the top of a large active volcano developed on the Africa continental crust in front of the Sicilian-Maghrebian thrust system. The volcano is located within a NW-SE trending tectonic depressions related to the opening during the Neogene-Quaternary of a rift system within the Pelagian Block. The area is characterized by a continental crust less than 20 km thick, by a relatively high heat flow (100 mW/m^2) and by positive Bouguer anomalies ranging between +40 and + 80 mGal. The structural setting of the island is strictly related to the rifting processes acting in this area and its large-scale setting is characterized by two main discontinuity systems trending NW-SE and N-S, respectively. The former structures have been interpreted as right-lateral strike-slip faults whereas the latter as normal faults. The overall geometry of these structures, due to Late Quaternary to Present deformation, has been interpreted as a large scale composite pull-apart basin whose general architecture controls the volcanism of Pantelleria. The island is also characterized by an intense ground fracturing associated to both volcanic and tectonic activity. These minor structures show a more complex pattern characterized by the occurrence of four systems of discontinuity that only partially correspond to the regional trends. The volcanism of the island was characterized by both effusive and explosive eruptions fed through time by minor mafic and predominant per-alkaline silicic magmas (pantellerites). The early history of the island (300-45 ka) was dominated by widespread acidic and peralkaline pyroclastic flows, subordinate fall-deposits and lavas, and two concentric caldera collapses. The first formed around 110 ka and the second at 45 ka, just after the emission of the Green Tuff ignimbrite (GTI). The most recent activity (< 25 ka) is characterized by widely diffused intracaldera pantelleritic (and subordinate trachytic) pumice fall deposits and subordinate small-volume pyroclastic flows and surges. Radiocarbon dating gave ages of 4-5 ka for the latest silicic activity, whereas historical records describe a basaltic eruption occurred in 1891, along NW-trending fissures, offshore northwest of the island. Silicic eruptions have mainly produced three types of volcanoes: pumice cones, shield volcanoes and partially collapsed edifices. Pumice cones are composed of fallout beds and pyroclastic-current deposits intercalated with variably welded layers. Shield volcanoes are built up by eruptions which began with explosive phases, continued with generation of spatter-fed agglutinates, and ended with massive lavas. Eruptions of per-alkaline magmas, characterised by high fluidity despite of their high viscosity, are the result of a complex combination of physico-chemical processes. The most recent volcanism is strictly related to the dynamics of the resurgence. Basaltic eruptions have generated cinder cones and lava flows. The island is also characterized by hydrothermal manifestations, including fumaroles and hypothermal to boiling waters, testifying to the existence of an active hydrothermal system. Recent studies highlighted also a huge diffuse CO_2 degassing of the island mainly concentrated in two anomalous degassing areas (Favara Grande area and Specchio di Venere lake). In these areas, located inside the most recent caldera, CO_2 levels lethal to small animals are often reached and worry about human health has sometime been

expressed. Moreover recent surveys evidenced in these areas also high levels in soil Rn, which creates also concern for human health. Furthermore the lake Nyos disaster highlighted the potential hazard connected with lakes in quiescent volcanic areas. The lake Specchio di Venere being located in one of the most exhaling areas could act as a potentially dangerous CO_2 trap. Pantelleria is also affected by recent deformation highlighted by an EDM and GPS monitoring network operating since 1978 by the INGV-Ct and covering the entire island. Strong geological and geophysical evidences, acquired through these geodetic techniques, support a recently proposed model that postulates the presence of a currently deflating shallow magma chamber. In this framework, in 1999 three tilt and GPS permanent stations have also been installed and new short-term ground deformation researches have been carried out to improve the monitoring of the volcanic hazard in this island. Moreover, a successful experiment with InSAR technique has been applied and better informations about the location of the shallow magmatic source have been achieved. Finally, in order to cover an important deficiency in the geophysical dataset, two permanent broadband seismic stations are going to be deployed by INGV-Ct on the island with the aim to classify the volcanic-related seismic aspects of Pantelleria and to improve the geometry of the seismic network in the area of the Sicily Channel.

Description of the Activities

The project is organized in 4 Tasks devoted to define: i) the major volcano-tectonic features of the island, ii) the short and long term ground deformation, iii) the definition of the magmatic and geothermal degassing and iv) the possible hazard scenarios.

Task 1. Volcano-tectonic features and feeding system

The task 1 is organized in two major research lines. The first concerns researches on the volcanic products to define the volcanological history and to evaluate the possible eruptive scenarios occurring in the island, whereas the second line is devoted to define the major volcano-tectonic structures and the lithospheric features of the volcano.

Volcanic products
UR coordinating: Orsi (Osservatorio vesuviano-INGV)
UR Participating: D'Antonio (Univ. Napoli), Landi (INGV-Pisa), Lanzafame (INGV, Catania), Rotolo (Univ. Palermo)

To define the volcanic history of the island, firstly field investigations, carried out using standard field survey techniques, will be performed to reconstruct a detailed stratigraphy of the more recent products (< 20 ky) also revising unpublished geological maps. Relationships between volcanic bodies and palaeomorphology will be also investigated. Filed investigations will be aimed to define the shape of the exposed rock bodies and their geometric relations. Studies will be realized to define the sedimentological features and dispersal of pyroclastic deposits (thickness, and maximum pumice and lithic clast of beds) and the rheomorfic characteristics of the variably welded deposits. In particular some key areas such as Mursia cinder cones and basaltic lava flows, and the silicic Cuddia di Mida pumice cone, Cuddia Mueggen shield and Cuddia Randazzo partially collapsed edifice will be accurately investigated. Moreover geo-volcanological investigations of the Agrigento-Sciacca coast will be carried out to verify the occurrence of volcanoclastic products related to known and unknown submarine eruption occurred on the Pantelleria district.
Laboratory studies on collected samples will include whole rock chemistry (XRF, ICP-AES, ICP-MS) as well as petrographic and compositional study of mineral and glass phases (SEM-EDS, EPMA). The results will permit to identify melt/mineral equilibria and, as a whole, to define the evolutionary history of the studied magmas. A melt inclusions study will be mainly directed to the determination of the volatile abundance. H_2O and CO_2 will be measured by means of FT-IR

spectroscopy in naturally quenched glasses. Chlorine and fluorine abundance, as well as major elements, will be measured in melt inclusions and residual glass by EPMA. Comparison and feedback with the results of experimental petrology obtained by UR-Rotolo will provide further constraints to the chemico-physical parameters of these magmas. The data obtained on the abundance of the different volatile components dissolved in melt in pre-eruptive conditions will be used to estimate the volatile pressure and the depth of storage of the different magmas at the time of crystallisation, taking also into account the contribution of the high abundance of halogens to the total volatile pressure. The relative variations of volatiles with different solubility will give insights into the degassing path of these magmas in pre-eruptive conditions, and will permit to assess the relationships between degassing modality and eruptive style of Pantelleria magmas. Isotopic analyses (Sr, Nd, Pb, B, O) will be also performed by TIMS at O.V., I.N.G.V. (Napoli) and at I.G.G., C.N.R. (Pisa). Rheological and thermodynamic properties will be moreover determined at Munich University measuring viscosity-temperature relationships, glass transition temperature, heat capacity, thermal history and effect of H2O on viscosity. The shear dry viscosity in the T range 1600-1100°C will be measured using a rotational viscometer. The dry and hydrous viscosity in the T range 400-800°C will be investigated using the micropenetration method. Glass transition temperature and heat capacity will be determined using a Differential Scanning Calorimetry. Volatile contents will be measured to investigate the structural complexity of peralkaline melts. H2O and CO2 contents will be determined by FT-IR at the O.V., I.N.G.V. on glass inclusions trapped in crystals and in the matrix glass; Cl and F contents will be determined through EMPA and/or ICP-MS analyses. The distribution of structural units in glass will be studied by experimental determinations of the Si and Al chemical environment through 29Si and 27Al NMR spectroscopy at the University of Trieste, in order to characterize peralkaline melt properties such as the degree of polymerization. The network distribution of hydrous species will be addressed by 1H NMR experiments in order to evaluate the H2O permeation and the role of diffusion during magma degassing. The role of F- will be explored by 19F through synchrotron spectroscopy. Isotopic data will be obtained to investigate the source of volatiles. Grain size analysis of loose pyroclastic rocks; components analyses of pyroclastic deposits; SEM morphoscopic analyses of pumice and ash particles; textural analyses of variably welded deposits and lavas in thin sections; density determinations of variably welded deposits; density-profiles reconstruction of selected pyroclastic units in various locations, also according to the palaeomorphology; aspect ratio determination of juvenile components in variably welded deposits will be also carried out.

Volcano-tectonic features
UR coordinating: Tortorici (Univ. Catania)
UR Participating: Brancolini (OGS, Trieste)

A detailed study will concern the recognition of the geometry and kinematics of the active tectonic features interacting with the landscape evolution and the measurement of parameters useful to reconstruct their evolution and activity vs. time. The expected results will consist of a preliminary mapping of the active structures, by interpretation of 1:5000 scale aerial photographs and elaboration of satellite SPOT and LANDSAT 5 TM imagery. The second step of the analysis will consist of detailed structural analysis that will be carried out along the principal fault segments to define the kinematics of the entire fault system affecting the island. These analyses will be made on the fault developed along the major structures and within the deformed volcanics. The whole deformation pattern of the island will be evaluated by the analysis of the distribution of tectonic fracturing. The fracture pattern will be evaluated by collecting data in structural stations taking into account geometric features, spacing and frequency. The kinematic analysis will be also useful to define the geometry of the main component of the present-day stress field acting on the island. A detailed mapping at scale !:10000 of the volcano-tectonic features (vent alignments, caldera rims, eruptive fractures ecc.) will be carried out. Lithospheric features will be investigated by the analysis

of several seismic lines acquired in the Sicily Strait between Pantelleria and Malta Islands (MS14, MS 19, MS 111, 116, MS 118-122) together with other seismic profiles acquired in the frame of the CROP (CRosta Profonda) Italian Project (M23A, M23AA, M24, M25, M39). In order to provide a fine reconstruction of the structural and sedimentary setting of the study area a non-conventional processing procedure will be performed (i.e., pre-stack depth migration) on key multichannel seismic lines (both MS and CROP profiles), to image in detail the rift-related structures, to individuate possible sub-surface volcanic bodies, and identify the principal seismogenic faults, particularly those associated with neo-tectonic activity. The identification of the main morpho-structural features will led then to compile a structural map of the investigated area, to be integrated with available bathymetric information. A gravity (free-air) and magnetic map to recognize and map the distribution of anomalous (volcanic) bodies in the surface and/or sub-surface, which are possibly related to the rift activity characterizing the Sicily Strait region will be created. The structural maps derived from seismic data interpretation, integrated with the geophysical maps (gravity and magnetic maps) will be used to model, through data inversion, the deep structural setting of the island of Pantelleria in the framework of the Sicily Strait lithosphere, and propose a plausible model for the rift system.

Task 2. Ground deformation
UR coordinating: Mattia (INGV, Catania)
UR Participating: Tortrici (Univ. Catania)

Short term and long-term deformation of the island will be investigated with geological and geophysical methods. Geophysical researches will be summarized in the following points:
1) Analysis of datasets from tilt and GPS permanent stations and from GPS discrete surveys will be carried out.
2) Comparison of the results with other data (geological, geochemical, etc.) finalised to a first model of magma transfer processes from depth to surface.
3) Definition of common procedures of data filtering from meteorological and, generally, from exogenous phenomena (tides, antropic environment) in seismic and ground deformation data.
4) Creation of a database of seismic events in the area of Pantelleria and, in general, in the channel of Sicily using mainly INGV data from seismic permanent networks but also data from all the mediterranean seismic networks.
5)Analysis of the seismic events related to the volcanic activity.
6)Modelling of strain fields induced by shallow and deep volcanic sources with InSAR data. A database of ERS and ENVISAT images will be realized in order to realize a complete time serie of ground deformation at the scale of the island since '90th.
7)Analysis of seismic data from temporary deployed seismic arrays.

From geological poit of view significant information on long-term vertical deformation affecting the island will derived by detailed study on distribution of marine surfaces and paleoshorelines. Uplifted marine notches, caves and vermetus bio-constructions will be detailed mapped to also define ground deformation curves and velocity diagram of vertical deformation. The analysis of marine terraces will be complemented by absolute dating of deposits sampled on different orders of the studied terraces to obtain precise age constraints necessary to evaluate the different vertical deformation rates. Combining ages and elevations of terraces and paleoshorelines with OIT stages of high sea-level stands and absolute sea-level variations will be thus possible to accurately evaluate the uplift rates affecting the analysed regions. This information will be compared with short term deformation data deriving from GPS and levelling networks. Finally the effects of the vertical uplift on the slope stability will be evaluated classifying the major landslides and rock-fall occurring on the island.

Task 3. Hydrogeological setting and geothermal system

UR coordinating: D'Alessandro (INGV, Palermo)

Reconnaissance soil gas survey covering the entire area of the island with an adequate number of randomly selected soil CO_2 flux measurement sites (4 sites/km^2) will be carried out. Soil flux measurements will be made with the method of accumulation chamber. Contemporaneously collected soil gas samples at the depth of 50 cm will be analysed both for chemical (N_2, O_2, CH_4, CO_2, Rn) and isotopic (CO_2-C) composition. The main gas manifestations will be also sampled and the gases analysed for chemical and isotopic composition. Data elaboration with statistical softwares will allow the production of the distribution maps of CO_2-fluxes and gas concentrations (CH_4, CO_2, Rn) and the estimation of the total diffuse CO_2 emission of the island. The obtained CO_2 degassing budget, together with the CO_2 solubility data obtained by the petrologic studies of task 1, will be important for the constrain the magma volumes of the magmatic feeding system. Detailed soil gas surveys of the most exhaling areas, evidenced by the previous surveys, with a higher measurement density (50 points/km^2) will be made. Basing on the results of the structural studies of Task 1 the degassing of the main structures will be also studied with a series of perpendicular traverses. Furthermore soil gas distribution maps (CO_2, Rn) will be the necessary basis for some of the thematic hazard maps of task 4. The set up of a continuous monitoring station at lake Specchio di Venere will be made after a preliminary survey around the previously identified high degassing area for the choice of the site. The station will automatically measure and acquire many parameters (CO_2 flux from the soil, soil temperature, CO_2 concentration in air at two (or three) different heights – (10,) 50, 150 cm – and meteorological parameters – temperature, atmospheric pressure, wind speed and direction, rainfall). Gas flux data acquired by the continuous monitoring station, will be compared with seismic data obtained by UR-Mattia to investigate possible correlations, and will be also necessary for the comparison of discrete flux measurements made in different periods. A reconnaissance survey of the waters of Specchio di Venere will be performed. Water samples collected at different depth along a transect of the lake will be analysed for their chemical and isotopic composition and for their dissolved gas content. This first survey will be made in the dry season followed by a second in the wet season. A survey of submarine hydrothermal vents will be carried out with a fishfinder along the coast of the island and in the area of the last underwater eruption. Obtained data will be helpful in correlating subaerial and offshore tectonic structures. Sampling of underwater released fluids will be made by scuba diving.

Task 4. Hazard mapping

UR coordinating: D'Alessandro (INGV, Palermo), Tortrici (Univ. Catania), Orsi (Osservatorio vesuviano-INGV)
UR Participating: Brancolini (OGS, Trieste), D'Antonio (Univ. Napoli), Landi (INGV-Pisa), Lanzafame (INGV, Catania), Mattia (INGV, Catania), Rotolo (Univ. Palermo).

The whole data obtained by the activities of the above mentioned tasks will be elaborated to construct hazard maps. A vents location map with relative magma composition erupted through time will be produced. For each explosive eruption, magnitude and energy will be evaluated. Plots of magnitude and energy variation through time, will be constructed. These eruption parameters, as well as the sequence of variable eruption phenomena during a single eruption, and its relationship with magma composition and vent position, will be statistically analysed to define the probability of occurrence of variable explosive eruption scenarios. For the effusive eruptions, often including low-magnitude explosive phases, the sequence of variable phases will be defined and correlated to the erupted magma composition and vent position. Also these data will be statistically elaborated to

define the probability of occurrence of variable scenarios. All collected data will be integrated to produce a single probability definition of the expected eruption scenarios. Probabilistic hazard maps for tephra fallout, pyroclastic currents and lava domes and flows will be constructed. Maps showing relations between CO2 degassing and fractures will be performed for key areas.

List of deliverables

Task 1: Volcano-tectonic features and feeding system
Deliverables: - Modelling of the mantle source characteristics - Magma chamber processes before and during eruptions – Physical and chemical parameters, and rheological properties of the erupted magmas – Kind and amount 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 - Stratigraphic sequence of the exposed deposits - Maps with pattern distribution of surface fractures, eruptive fractures and vent distribution - Data base of available reflection and refraction seismic data -Data base of the gravimetric data in the Sicily Channel-Reinterpreted seismic profiles – Density distribution models based on gravimetric data – Structural map of the offshore Pantelleria island.

Task 2: Ground deformation
Deliverables: Database of seismic events in the area of Pantelleria and Sicily Channel - Model of strain fields induced by shallow and deep volcanic sources with InSAR data - Distribution map of Quaternary paleoshoreline and marine terraces - Late Quaternary-Holocene and present uplift rates - Map of slope stability and landslides.

Task 3: Magmatic and geothermal degassing
Deliverables: - Spatial distribution maps of soil gas concentrations of CO_2 and Rn and soil CO_2 fluxes - Detailed spatial distribution maps of soil gas concentrations of CH_4, CO_2 and Rn and soil CO_2 fluxes of anomalous degassing areas - Map of submarine hydrothermal vents - Identification of relationships between tectonic and volcano-tectonic structures and soil CO_2 outgassing – Gas hazard estimation - Hydrological and geochemical budget of the lake Specchio di Venere with special emphasis on CO_2 accumulation - Quantification of CO_2 outgassing of the island.

Task 4: Hazard mapping:
Deliverables: – Probability hazard map for opening of a new vent - Eruption scenarios - Probability tephra fallout hazard map - Probability pyroclastic currents hazard map – Classification and volume estimation of landslides deposits - Surface gravitational movements hazard map – Gas hazard map.

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TABLE MAN/MONTHS

U.R	Institutions	Principal Responsibles	Task1 Volcano tectonics and feeding system	Task2 Ground deformation	Task3 Magmatic/geothermal degassing	Task4 Volcanic hazard	Mesi p. cofin.	Mesi p. rich.
UR-1	OGS Trieste	Brancolini	@				16	
UR-2	INGV-PA, INGV-Rm1, UniPa	D'Alessandro, Pecoraino, Pizzino, Parello			@		40	
UR-3	UniNa, UniTri, INGV-OV, CNR-IGG, Uni-Muenchen (D)	D'Antonio, Dini, Petrini	@				44	
UR-4	INGV-Rm1, UniCa, UniPi, CNRS-LPS (FR)	Landi	@				21	
UR-5	INGV-CT, UniFi	Lanzafame, Santo	@				26	
UR-6	INGV-CT	Mattia, Bonaccorso		@			38	
UR-7	INGV-OV, UniTri, UniNa	Orsi, Isaia, Scaillet S.	@			@	49	
UR-8	UniPa, CNRS-Orleans (FR)	Rotolo, Pichavant	@				14	12 (UniPa)
UR-9	UniCt, INGV-CT, INGV-Rm1	Tortorici, Monaco, Grasso, Catalano	@	@			62	24 (UniCt)
Totale							310	36

SUB-PROJECT V3_7 – PANTELLERIA

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	OGS-Tri	Brancolini			2000	2000	1500	1500	7500	7500		
UR-2	INGV-PA	D'Alessandro			8000	8000	2000	2000	15000	14000		
UR-3	UniNa	D'Antonio			4500	2400	1000	600	4000	7500		
UR-4	INGV-Rm1	Landi			3000	1500			3000	4500		
UR-5	INGV-CT	Lanzafame			1700	1700	800	800	6000	6000		
UR-6	INGV-CT	Mattia			2000	2000	4000	4000	7000	7000		
UR-7	INGV-OV	Orsi[1]			4000	4000	1000	1000	7000	11000		
UR-8	UniPa	Rotolo	16000	4000	1000	1000	3000	3000	2000	2000		
UR-9	UniCt	Tortorici	20000	20000	3000	3000	1000		7500	9000		
		TOTALE	**36000**	**24000**	**29200**	**25600**	**14300**	**12900**	**59000**	**68500**		
GRAN TOTALE: 269500												

[1]8000 euros (4000 each year) included under the voice "Consumi e servizi" will be provided to CEA-CNRS (Gif-Sur-Yvette, FR) for research activities under the responsibility of S. Scaillet.