Project V2- Monitoring and research activity at Stromboli and Panarea

Responsibles:

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The main tasks individuated in the context of the V2 project on Stromboli and Panarea are described on the basis of the contents of the attached C on the institutional decree of the coordinating commission of new projects of the "Framework convention DPC-INGV 2004-06", and on the basis of the general framework of objectives of specific concern for the DPC.

The present project will be constructed through a strong integration of the research units (RU) and the coordination of other projects, with particular regard to the V1 ("Prosecution of already funded activities in the GNV framework in 2003").

The project in its entirety will be based on a series of "task forces" among which researchers of diverse RU may encounter each other. The main goal is to stimulate research in synergy also by singling out mixed task forces in which the transverse nature of the disciplines can be implemented. It is therefore recommended right from the start that groups are created with interdisciplinary expertise aimed at resolving specific problems.

The aim of the present project on Stromboli and Panarea is to stimulate and promote research and studies orientated at supplying precise answers to the problematic of prime concern for Civil Protection. For Stromboli, such problematics are essentially made up of estimating the danger related to the various manifestations of volcanic activity (effusive and explosive) and slope instability phenomena of the edifice, with particular reference to the Sciara del Fuoco. For Panarea, the estimate of danger related to the underwater escalation zone to the east of the island, in the Lisca Bianca-Dattilo-Bottaro locality and its eventual connection with a magmatic system at depth, is of particular importance. Moreover, the definition of "critical levels" constitute activities of particular concern, or rather of the ensemble of indicators that may suggest significant status changes in the volcanoes under study. In particular, a more fitting understanding of the structure of Stromboli, of its feeding system and the mechanisms that govern the explosive activity is crucial for the mitigation of volcanic risk, also in consideration of the fact that the most powerful eruptions are among the events of greatest danger.

Lastly, it should be specified that the activities of implementing and boosting the different monitoring systems are not within the scope of the present project, being foreseen in another section of the DPC-INGV convention.

In the following, a brief description of the aims of the project is reported, indicating the lines of activity of greatest concern and the main expected achievements for each volcano.

Research line 1: Stromboli

Task 1. Studies and investigations aimed at the reconstruction of the present structure of the volcano and its feeding system (Stromboli)

A more suitable understanding of the internal structure of the volcano, its feeding system and its crustal roots, surely represent the basic tool to comprehend its activity, to develop models used for the study of the source mechanisms of seismic-volcanic events and the deformation field induced by

magma upraise mechanisms in the storage zones and along the feeding conduits, useful for estimating danger and critical levels of the volcano.

WP 1.1: Geological-structural studies and research aimed at reconstruction of the volcanic structure and feeding system

In the last ten years, there has been a notable contribution to the understanding of the entire structural evolution of the volcano. Thus different "caldera' type summit collapses have been individuated, spaced out in the oldest phases of the growth of the volcano, as well as diverse lateral "sector" collapses during the Holocene. The structural and stratigraphic study of the dykes, moreover, has allowed reconstructing the geometric evolution of the feeding system of the summit part of the cone. Given that this system of dykes is magnificently exposed at Stromboli, and taking account that there are dykes of very recent age, it is auspicious that they are analysed with greater detail, above all through a strong interdisciplinary approach that integrates structural, stratigraphic, petrographic, geochemical data, and numeric modelling. This would represent a further improvement and completion of work begun and started in 2004 in the project V1. In addition, there is a need to proceed with the mapping of the lava flows from Holocene fissure eruptions outside the SdF; these, representing the surface expression of dykes of very recent ages, will be integrated with all the other data described above. Furthermore, a strong collaboration with the group that is to pursue task 1.2 is to be hoped for, in such a way as to correlate also the geophysical data.

Deliverables:

1. Structural models of the volcano
2. Distribution map of Holocene dikes
3. Distribution map of lava flows from Holocene fissure erutpions
4. Scenarios of preferential diking in the cone based on the present shape of the volcano and the various possible dike parameters

WP1.2: Integration of geophysical methods for the study of the structure of the edifice and its deep roots

The recent experiences of acquisition and elaboration of active seismic data and seismic tomography through local earthquakes in volcanic areas, have shown how the joint use of the different recorded seismic phases and their inversion together with that from gravimetric data, may provide a detailed three-dimensional image of the volcanic structure and its feeding system, including eventual intracrustal magma reservoirs. This picture may be improved through other kinds of geophysical investigations, such as measurements of spontaneous potential, of deep geoelectrics and electromagnetics that today seem able to integrate the results obtained by seismic tomography. This is thanks to notable developments made in these fields in three-dimensional modelling that allows evaluating the presence of anomalies more precisely. At Stromboli owing to the lack of recorded local earthquakes, as natural sources useful for tomographic purposes and the high cost of a 3D experiment, a preliminary 2D tomographic study may be performed, through active seismics (explosions at sea and/or foro a terra). Such a study, as preparation to realising a future high resolution 3D tomographic study, should be integrated with a *receiver function* analysis of the teleseismic phases to identify the main discontinuities beneath the volcano.

Deliverables:

1. 2D seismic tomography sections of the volcano
2. 2D electric tomographic sections
3. Identification of the main deep discontinuities

Task 2. Evaluation of the dangers of effusive and explosive activity (Stromboli)

The eruptive crisis of December 2002- July 2003, the large scale landslide of 30 December 2002 that also affected the submarine part of the volcanic edifice at Sciara del Fuoco, the *tsunami* that it caused as well as the paroxystic event of 5 April 2003, focused attention on the need to define "critical levels", or rather to characterise well the ensemble of indicators that can highlight important status changes of this volcano. Obviously, the reduction of volcanic risk at Stromboli entails a better understanding of the surface feeding system (Task 1). The studies of a volcanological, petrological nature, on the volcano dynamics and the powerful monitoring device that exists today, allow to be able to tackle the main problematic on estimating the dangers related to the various manifestations of volcanic activity (effusive and explosive) and to the phenomena of instability of the slopes of the edifice, in particular the Sciara del Fuoco (Task 3).

WP 2.1: Analysis of explosive Holocene activity

Although numerous studies on explosive activity have been carried out recently, further improvements in the understanding of the explosive Holocene activity are possible and desirable, in terms of eruptive mechanisms, typology and distribution of emitted products, chronology of eruptive events; estimate of the probability of occurrence of volcanic phenomena in terms of typology, scale and recurrence of expected events; the study of the relationships between volcanic activity and lateral collapses. The research group tasked with this objective should interact and take account of the results in progress that will be reached in particular in the context of the tasks 1 and 3.

Deliverables:

1. Reconstruction of eruption history and dating of the principal Holocene explosive events
2. Characterisation of the main explosive Holocene eruptions and reconstruction of their eruptive dynamics
3. Evaluation of the occurrence frequency of volcanic events.

WP 2.2: Dynamics of modern explosive activity

In the course of the last years, the modern eruptive activity at Stromboli has been the object of many investigations of a volcanological and petrological nature. The studies carried out have significantly contributed to improving understanding of the ordinary eruptive processes related to the external and internal dynamics to the conduits and to better characterising the petrology of emitted products. The research carried out on the ordinary explosions and on the paroxystic events have highlighted a close dependence in the dynamics of the magmas in relations to their volatile content. In the field of the forecasting of the greatest danger eruptive phenomena, it proves of basic importance to understand the reasons that lead to the sudden rise of highly gas-rich magmatic masses able to produce the most violent explosions and/or paroxysms. Such studies should contribute to understanding the very mechanism of the biggest explosions through the study of emitted products and through the data deriving from visual (telecamera), petrological and geochemical monitoring and should equally be aimed at seizing on eventual precursor phenomena.

Deliverables:

1. Sampling and mapping of the products of ordinary activity and products emitted during past modern paroxysms
2. Laboratory measurements on magma properties

3. Relationships between eruptive dynamics and surface feeding system of the volcano
4. Evaluation of the trigger mechanisms of paroxystic eruptions; analysis of current activity.

WP 2.3: Geophysical studies and researches aimed at defining times and modality of recharging of the surface feeding system

Following on from the implementation of the geophysical monitoring system (seismic, ground deformation, magnetic networks etc.) and observation (telecamera networks) at Stromboli and its programmed development, it will be possible to estimate in an ever precise way in the next years, in real or almost real time, the fundamental parameters associated with the explosive activity of the volcano and define the times and modalities of recharging the system with the aim of establishing the relationships between these parameters and the released energy. This obviously in reference also to the explosive phases of paroxystic kind and to verify new effusive eruptions. Although numerous studies have been conducted on the explosive activity at Stromboli, in relationship to possible improvements that might derive from a more suitable understanding of the volcanic structure and its feeding system (Task 1), it is hoped that in the future there may be notable improvements in comprehending the release mechanisms and the volumetric variations of the sources of the individual explosive phenomena. This particularly goes for the paroxystic events and for the localization of deep and surface volumes of the feeding system affected by the same phenomena.
The extension to the sea of the seismic network of Stromboli through the deposition of a first nucleus of OBS/H around the island constitutes one of the objective of notable interest, both to study the phenomenons related to the SdF and to understand the mechanisms of deep recharge and of the seismic activity along seismogenetic structures. But the costs for the instrumentations should re-enter in the monitoring financings. While inside to the present project could find space the studies and the researches and the possible costs for experimentations.

Deliverables:

1. Broadening of the analysis techniques of VLP signals
2. Optimization of the automatic procedures for the inversion of the source function of the VLP events Improvement in the automatic recognition techniques of the different types of seismic-volcanic signals recorded by implementing analysis procedures both in time domain as well as frequency
3. Deformation fields induced by recharging phenomena in the diverse levels of magma “storage” at Stromboli by means of ground deformations data.

WP 2.4: Identification of precursor phenomena

The geophysical phenomena that precede and accompany almost all volcanic eruptions are in general variations in the characteristics of seismic activity and in ground deformations. In the literature, however, there are reports of different cases in which eruptions, both explosive as well as effusive, are accompanied by other kinds of variations geophysics and geoghemical. Nevertheless, the casuistic reported for these latter phenomena is not yet sufficient to be used as possible precursors, while as concerns eventual variations of seismic and/or ground deformation phenomena, further and more in depth research are desirable, given the fact that also for these disciplines there is no well defined casuistic at Stromboli.

WP 2.5: Modelling the eruptive processes

The study of the action of upraise conduits and the possible systems of intermediate storage on the strain field proves fundamental to understand the dynamics at work and for the evaluation of its possible evolution. In general, the study of the action of the conduits on the *strain* field is an argument that has been little tackled in literature and thus it deserves an in depth analysis especially at Stromboli. The study of the source processes of the seismic-volcanic events depends on the degree of resolution reached in the understanding of the volcanic structure that affects the degree of precision and the accuracy that may be reached in the identification of the systems of forces at play, in their distribution and amplitude and in the definition of their *time histories*. The low latency GPS network with high sampling frequency has proved, during the last emergency at Stromboli, to be a very versatile tool able to furnish useful data for modelling purposes, allowing modelling the surface source that acted on occasion of the paroxystic explosion of April 5, 2003. A notable contribution to the processes of surface and deep feeding in the future may derive from the elaboration of reliable physical models, useful to simulate the eruptive processes (development of the lava fields, of the eruptive columns and dispersion of the ejected products) and to forecasting the large energy explosions.

Deliverables:

1. Modelling of strain fields caused by the action of the conduit/s, and simulation of expected deformation fields
2. Models of simulation of the eruptive processes
3. Study of the seismicity associated with strong explosions aimed at constraining the variations at depth of the fragmentation level

Task 3. Evaluation of possible scenarios of deformation and dynamics of the Sciara del Fuoco (Stromboli)

The historical and stratigraphic data document that the Stromboli system is in its present condition for a little less than two thousand years. Such behaviour has proved exceptionally stable and rarely disturbed in this arc of time. However, in analogy to what occurred during the recent eruptive crisis of 2002-2003, the geological-structural research into the last 10 Ky of its evolution have shown how the volcano has undergone important slope collapses. One of the biggest collapses has moreover been related to a great explosive event whose products covered the entire island and whose dynamics may be interpreted as a product of the sudden depressurization of the magmatic and geothermic system.

Specific sub-goals are: the definition of the deformation modalities that may also affect different portions of the SdF, both regarding depth as well as location, through the integration of structural, volcanological, lithological, geotechnical, analogue and numerical data; studies into the causes/concause that have led and may lead to various scenarios of deformation through interdisciplinary studies; the integration of these data with recent studies into the dynamics of the volcano and the existing monitoring system. The research group tasked with this objective should interact and take account of the on-going results to be reached in particular in the context of tasks 2 and 3.

Deliverables:

1. Expected deformation scenarios of the SdF on the grounds of possible casuistic
2. Determination of the thermal, hydrothermal and pore pressure contributions on the instability of the SdF
3. Evaluation of the hazard linked to the dynamics of the SdF slope.

Task 4. Studies aimed at understanding the circulation of fluids (Stromboli)

The geochemical surveillance at Stromboli up to the beginning of 2000 was still in an embryonic stage, essentially consisting in discontinuous measurements of the chemical and isotopic composition of the gases emitted from the accessible fumaroles located in the summit part of the crater. The eruptive crisis of 2002-03 led to a consistent increase in geochemical activities. In the framework of the present project, the geochemical studies and research should be aimed at a better understanding of the transfer mechanisms of the magmatic gases from the deep system towards the surface and the individuation of interaction mechanisms with surface fluids. Possible sub-goals are the studies for the formulations of models based on the continuous checks in the crater area, of the ground degassing, of temperature and the spontaneous potential in the summit zone, on the measurement of the chemical composition of the plume, on the checking of the chemical and isotopic composition of the aquifers, of the ground degassing of CO_2 and Radon in the Stromboli town.

Deliverables:

1. Data sets on geochemical discharge
2. Formulation of geochemical models on the relationships between the geothermic system and the gas interchange with the deeper magma sources.

Research line 2: Panarea

Task 5. Reconstruction of the explosive Holocene events and evaluation of the presence of a magmatic body in the area (Panarea)

Recent studies have shown the presence in the area of Panarea of deposits attributable to younger explosive activity than believed to date. Taking also into account of the consistent increase in geochemical activity in the zone during the crisis of 2002-03, the following sub-goals are proposed: reconstruction of the most recent volcanic activity in chronological terms of the eruptive events, eruptive mechanisms, typology and distribution of the emitted products; studies aimed at the evaluation of the presence of a magmatic body in the area; definition of the relationships between the island of Panarea and the substrate and of the relations with Basiluzzo and the minor islands. We underline the importance of finding evidences of freatic explosions occurred in the past and whose re-occurrence could create some problems in the urban areas of Panarea.

The research group responsible for this task should interact and take account of the on-going results to be reached in the context in particular of task 7.

Deliverables:

1. map of the distribution of the most recent explosive/effusive products
2. dating of the main most recent volcanic events
3. characterisation of the eruptions and reconstruction of the eruptive dynamics
4. representation of the eventual magmatic body

Task 6. Definition of the conditions leading to the development of the fracture field of the 2002-03 crisis along the Panarea-Stromboli axis (Panarea)

At the end of 2002 there were various volcanic and deformation phenomena in the area of Panarea-Stromboli. The temporal coincidence of the phenomenologies and the breadth of the area affected pose notable questions on the causes and dynamics of the processes. The following sub-goals are believed important: analyses of the possible causes triggering the NE-SW-striking fracturing of the Panarea-Stromboli system; influence of the regional tectonics on the local stress/deformations fields of eastern Eolian islands through the integrations of numeric, analogue and real data.

The research group responsible for this task should interact and take account of the on-going results which will be reached in particular in the context of task 7.

Deliverables:

1. map of the late-Quaternary regional structures
2. map of the regional/local stress field
3. fracture models of the area

Task 7. Studies aimed at understanding fluid circulation (Panarea)

The crisis of Panarea in November 2002 has led to a notable increase in the geochemical activity following the submarine escalation action to the east of the island, in the Lisca Bianca-Dattilo-Bottaro locality. It would be wise to formulate models based on fluid circulation during the 2002 crisis and on the post-2002 data set. In order to improve the comprehension of the meaning of the geochemical composition of the gases outpoured from the undersea fumaroles, it would be wise to obtain isotopic data on $^{3}He/^{3}He$ of the main magmatic products of the Panarea eruptive complex, and to investigate the geochemical aspects linked with the interaction between gas of magmatic origin and/or geothermics with sea water.

Deliverables:

1. models of fluid circulation in the area
2. models of the cause of the crisis of 2002