Workshops on Marine Research Drilling (Magellan Workshop Series)

Drilling through an active caldera, offshore Campi Flegrei, Eastern Tyrrhenian margin

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International Continental Drilling Program (ICDP)
Campi Flegrei Caldera Deep Drilling Workshop

Napoli, 13-15 November 2006

Conference Centre - Città della Scienza, Via Coroglio, 57 - 80124 - Napoli
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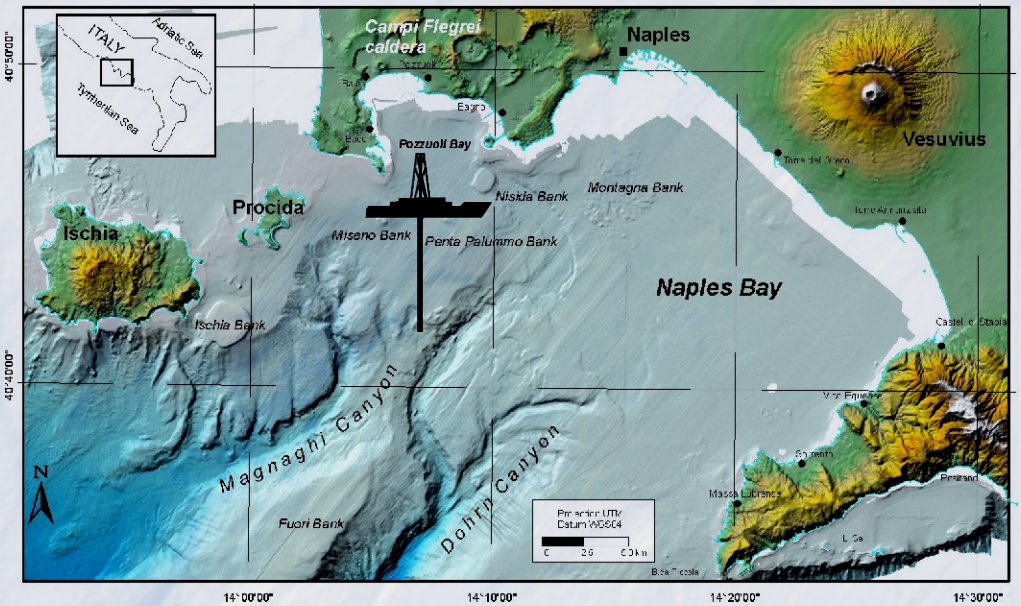
University of Napoli Federico II (Mineralogy Museum), Via Mezzocannone, 8 - 80128 - Napoli



FINAL REPORT

M. Sacchi

Co-sponsored by

Institute for Coastal Marine Environment
Italian Research Council (CNR)

University of Napoli Federico II

Ordine dei Geologi
della Campania

European Consortium
for Ocean Research Drilling

REPORT ON THE ESF MAGELLAN WORKSHOP:

Drilling through an active caldera, offshore Campi Flegrei, Eastern Tyrrhenian Margin

In conjunction with and co-funded by the International Continental Drilling Program (ICDP)

Convenor

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Workshop places and dates

Naples, 13-15 November, 2006

- Mon. 13 November 2006 08:30 – 17:00 (Conference Centre "Città della Scienza" Via Coroglio, 57)
- Tue. 14 November 2006 09:00 – 17.00 (University of Napoli Federico II - Mineralogy Museum, Via Mezzocannone, 8)
- Wed. 15 November 2006 09:00 – 18.00 (University of Napoli Federico II - Mineralogy Museum Via Mezzocannone, 8)

1. SUMMARY

The study of volcanic continental margins and/or island arc volcanism is fundamental in the understanding of Solid Earth cycles and geodynamics. In the past decades, with a few exceptions, ODP and DSDP have realized only a limited exploration of volcanic continental margins. However, since the advent of Mission Specific Platforms, in 2003, IODP has broadened its range of strategies and actions and offshore drilling has expanded to fully include continental margins, which are among the principal loci of the populated Earth for natural resources and geohazards. In particular, knowledge of volcanic hazards has become a dominant issue for the scientific and social community worldwide.

Active calderas are major volcanic features of the Earth's crust associated with shallow magma reservoirs, high geothermal gradients, and geodynamic unrest often documented through historical time. Because explosive caldera-forming eruptions are also among the most catastrophic geologic events that may affect the Earth's surface, calderas are ostensibly the sites of major interest for both scientists and governmental institutions worldwide. The Campi Flegrei caldera, located on the Campania coast, west of the town of Naples, Italy, represents an ideal natural laboratory for a strictly coordinated IODP-ICDP research addressed to the understanding of the most explosive volcanism on the Earth, and its impact on a densely populated area.

During the workshop, held in Naples on 13-15 November, 2006, 45 participants from research European institutions from 6 European countries, the United States and Mexico, gathered to discuss the key scientific issues surrounding the investigation of highly explosive volcanism at continental margins and/or volcanic arcs. Researchers represented a wide range of disciplines related to the field of volcanology research, and included geology, geophysics, geomorphology, petrology, geochemistry, geochronology, numerical and analogue modelling, etc.

The workshop was intended to bring together experts, young researchers and other representatives from the academia and industry involved in marine research drilling. Participants were asked to contribute to scientific debate on volcanic processes and associated hazards over coastal areas and, in this perspective, identify problems that can be addressed by marine and continental drilling, with reference to the Campi Flegrei Caldera, Southern Italy, as a case history. The workshop programme addressed data integration, and the building of a scientific rationale for drilling strategies and scientific partnering through a multidisciplinary approach, by linking geology, geophysics and geotechnology.

The event has been among the first European efforts to assess volcanic hazard within the context of IODP and is likely to be a reference for future initiatives towards an implementation in the IODP-Initial Science Plan and the eventual development of a "geohazard" Mission proposals. Participants provided evidence that the peculiar setting and features of the partially submerged Campi Flegrei Caldera makes it an ideal natural laboratory for future joint ICDP-IODP research.

2. INTRODUCTION

The Campi Flegrei is an active volcanic district that lies west of the town of Naples near the Pozzuoli bay coastline (Fig. 1). This area represents a very mobile segment of the eastern Tyrrhenian margin during the late Quaternary and may be regarded as a privileged natural laboratory to study the interplay between tectonics and explosive volcanism associated with rifted back-arc margins (Milia and Torrente, 1999; Acocella et al. 1999; D'Argenio et al., 2004).

Many authors agree in considering the Pozzuoli bay and its surroundings as a remnant of a quasi-circular caldera, about 13 km in diameter. Recently De Vivo et al. (2001) presented evidence for previously unrecognised explosive events at 205, 157 and 18 Ka in the Campania Plain, in addition to the well-known ignimbrite eruption at 39 Ka. (De Vivo et al., 2001). The caldera formed as a consequence of a major eruption and collapse that occurred about 39 ky BP, and caused the emission of some 80 km3 of DRE (Dense rock equivalent) and the emplacement of ignimbrite sheets all over the present-day Campania Plain. A co-ignimbritic air-fall layer (Y5) extending as far as the eastern Mediterranean and north-eastern Europe, has been detected. After this gigantic event many large to medium scale eruptions occurred around 15 ky BP and in the past 6,000 years (Fig. 2). The most recent volcanic activity occurred in 1538 A.D. Magma-related activity clustered in the centre of the caldera seems to be testified by extensive hydrothermalism, very recent episodes (1970-71 and 1982-84) of shallow seismicity and ground deformation (exceeding rates of 100 cm/year in the years 1983-1984) (Berrino et al., 1984; Dvorak and Berrino, 1991; De Natale et al., 2001; Battaglia et al., 2006)

The Campi Flegrei is a typical example of collapse caldera (Fig. 2), which has the highest recorded ground movements not immediately followed by eruptions. In this area, first colonized by Greeks and home to the largest Mediterranean military fleet during the Roman times (Baia, on the west side of caldera), there is the longest historical record of ground movements associated to volcanic activity, revealed by marine incrustations and molluscs on the Roman and medieval buildings (Troise et al., 2006). The secular deformation of this area is subsidence, at a rate of about 1.5-1.7 cm/year, with some periods of large and faster uplift (Fig. 3a). Historically, three such uplift periods are evident: the first one occurred from 80 to 230 AD, the second from 1441 to 1538, culminating in the last eruptions in the area from 1969 is still in progress (Fig. 3b). The latter period is characterized by episodes of very fast deformation rates, followed by periods of minor subsidence. The total uplift since 1969 to 1984 was 3.5 m, and uplift rate in the period 1983-1984 exceeded 1 m/year. After 1985 a relatively fast subsidence started until at the end of 2004; since the last year a new uplift episode is in progress, reaching 4 cm till now, 2 cm of which in the last two months (Fig. 3c). The Campi Flegrei Caldera is partially submerged for about 60 % of its surface.

The Campi Flegrei probably represent the most interesting example in the world of an active caldera that develops across a densely populated continental margin. As it partially develops beneath the sea water, over the inner continental shelf of Southern Italy, the Campi Flegrei area is an ideal site to test the potential of IODP shallow water drilling on a volcanic continental margin by a long-term multi-platform drilling programme including land-sea transects, in the frame of a first fully integrated IODP-ICDP proposal in the Mediterranean (Figs. 4 and 5).

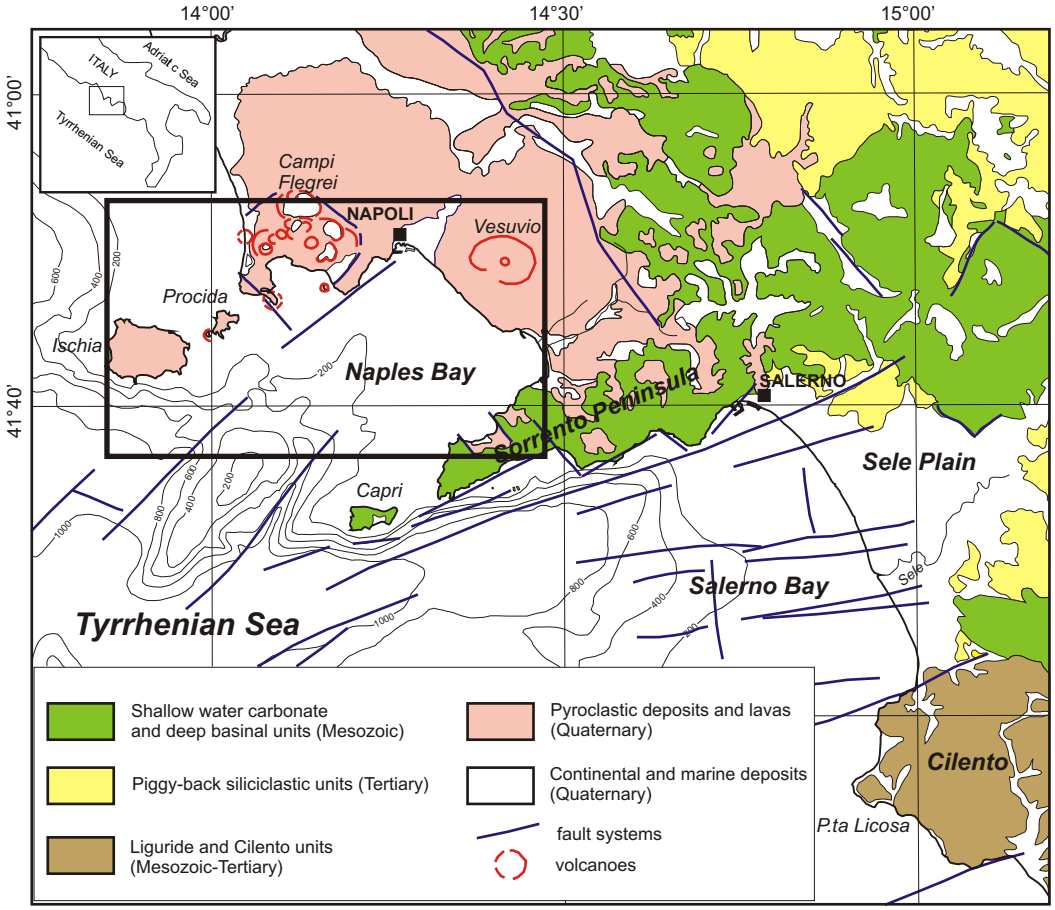

Fig. 1. Tectonic sketch-map of the Campania continental margin (Eastern Tyrrhenian Sea) with location of the IODP preproposal #671 (Campi Flegrei drilling project) area.

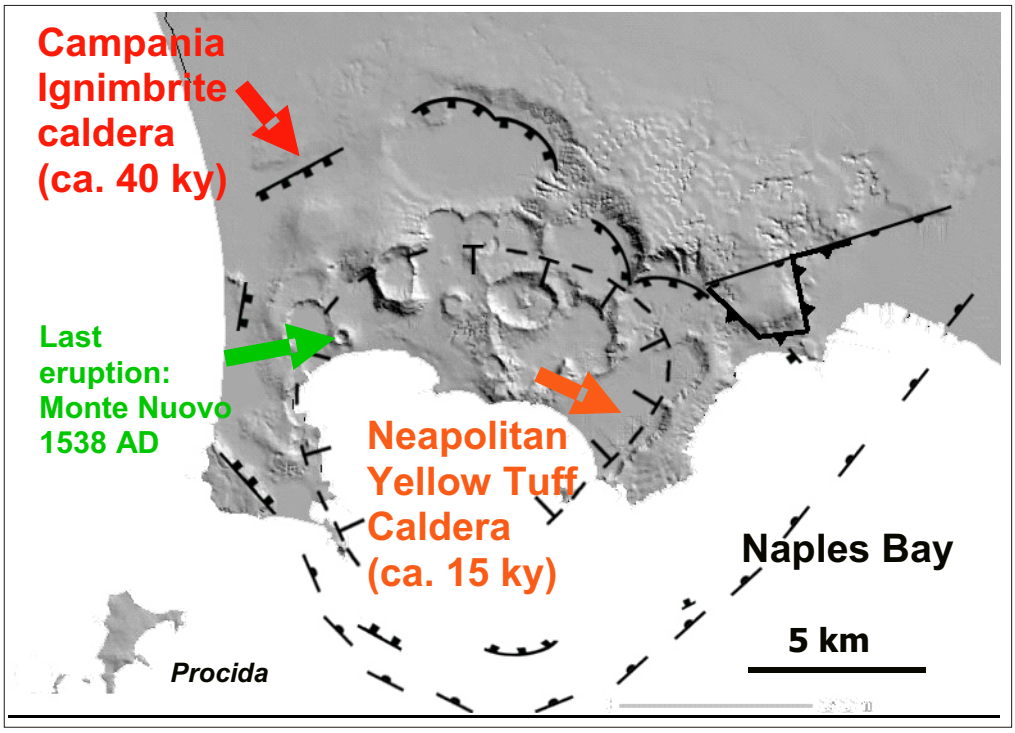

Fig. 2. Collapse Rims of the Campi Flegrei nested caldera .

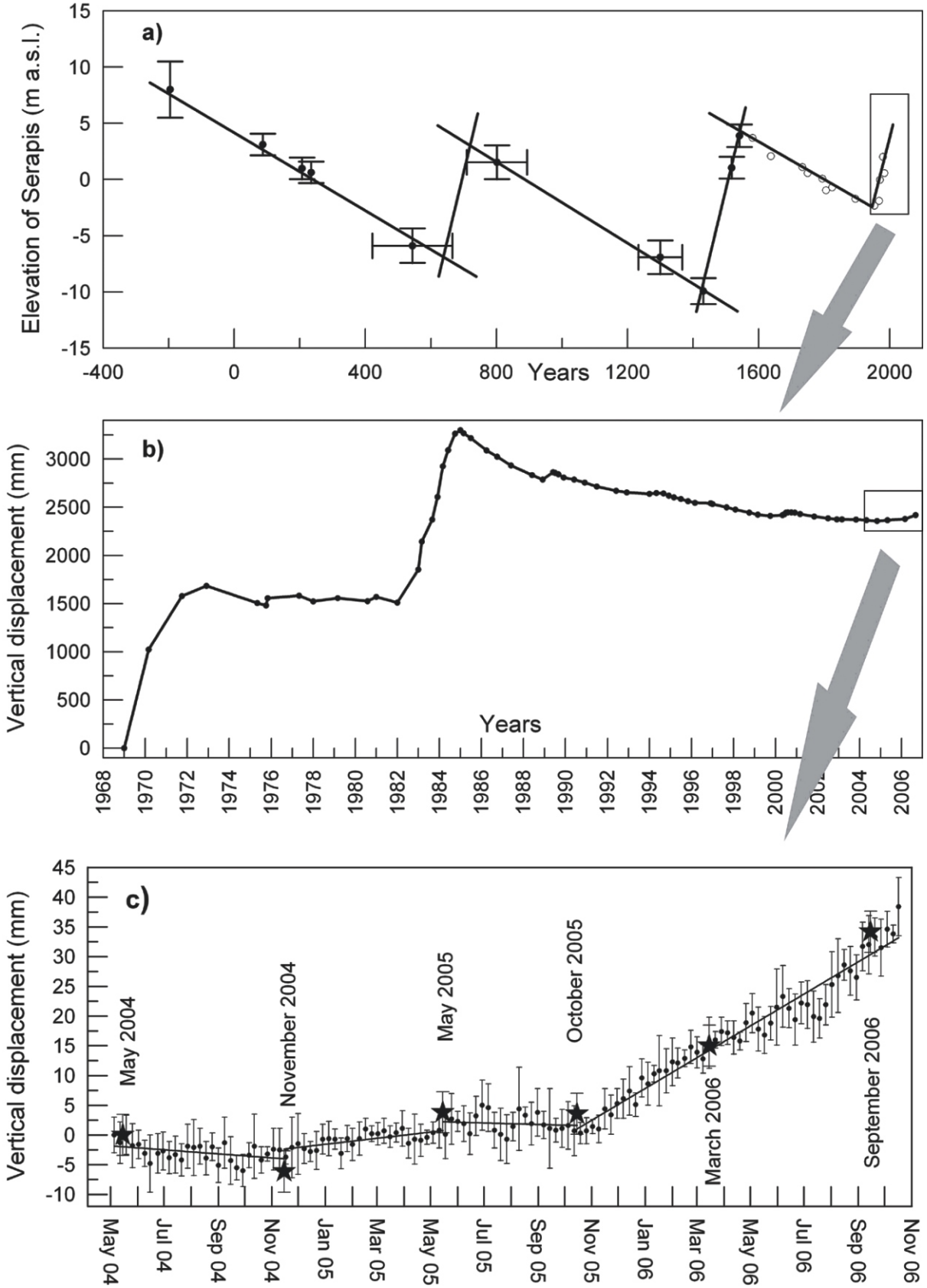

Fig. 3. Ground deformation at Campi Flegrei as a function of time, at three progressive enlargements. a) Schematic vertical movements history at Macellum in Pozzuoli, known as Serapis Temple. Black circles and white circles represent data points from various sources (see De Natale et al., 2006 and references therein). b) Vertical ground displacements as recorded at Pozzuoli Harbour by levelling data in the period 1969-2006. c) Detail of vertical displacement from May 2004 to October 2006 as recorded from: CGPS (dots); precision levelling at bench mark in Pozzuoli harbour (stars). Errors on CGPS and levelling data (1σ) are also shown. Redrawn after Troise et al. (2006).

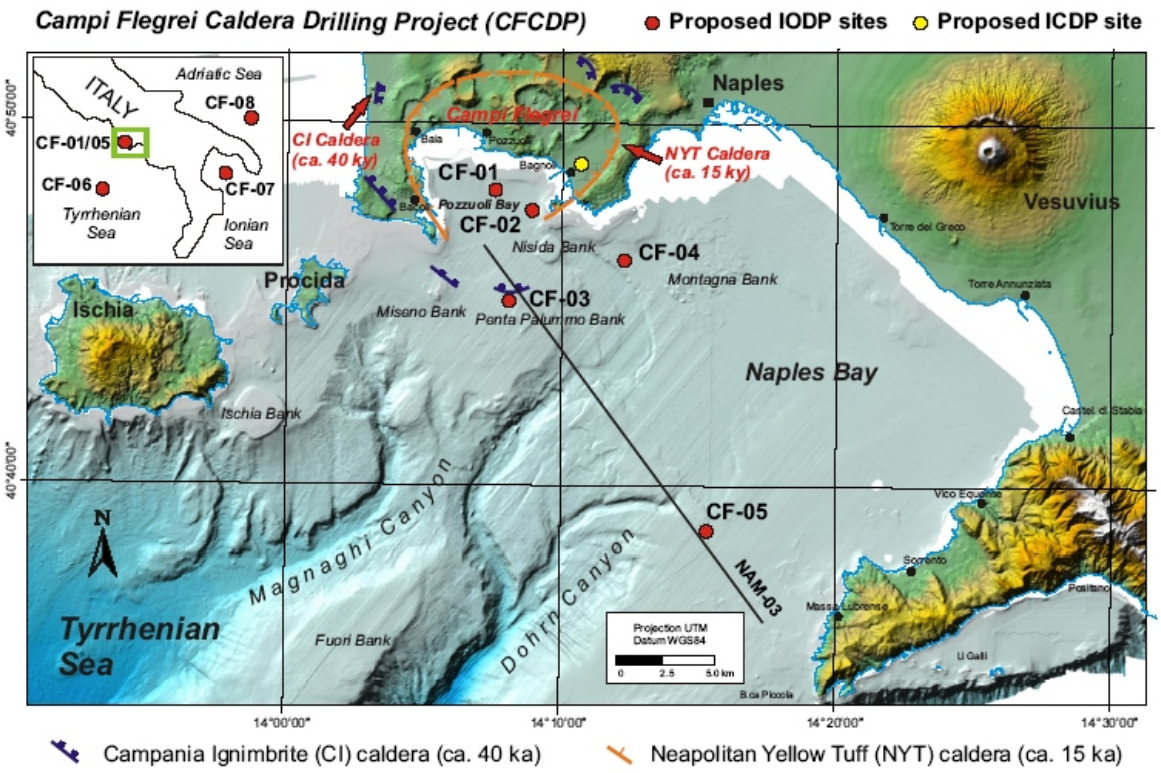

Fig. 4. DTM of the Naples Bay with location of the proposed drill sites and a sesimic profile selected from the site survey database. Red circles are the proposed IODP drill sites; yellow circle is the drill site proposed by the same scientific partnership to ICDP.

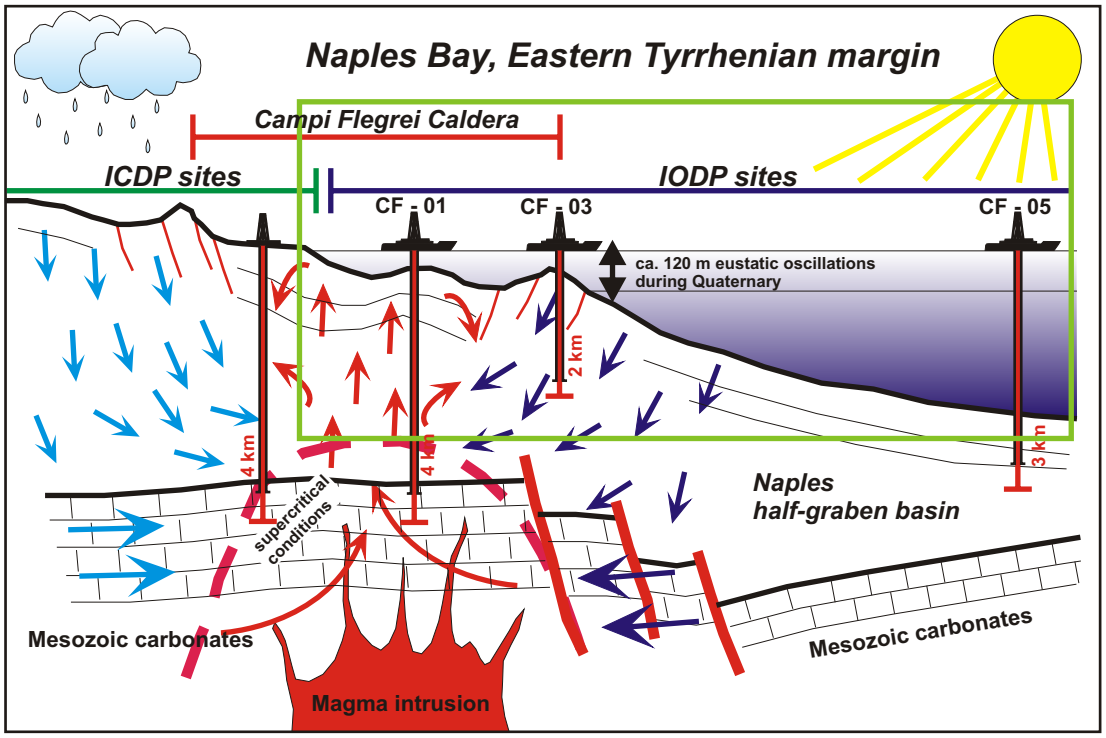

Fig. 5. Conceptual framework of the Campi Flegrei Caldera and tectonic setting of the Campania continental margin. Green box represents the structural level of specific interest for the present proposal and its relationships with IODP and ICDP drilling targets.

3. DESCRIPTION OF THE SCIENTIFIC CONTENT AND DISCUSSION AT THE EVENT

The workshop included a plenary session (together with the Continental Drilling community) and a short field trip to the Campi Flegrei on the first day (13 November 2006 - Conference Centre "Città della Scienza"), followed by thematic sessions and Working Groups meetings on the following next days (14-15 November 2006 - University of Napoli Federico II - Mineralogy Museum).

The ICDP-ESF Magellan Plenary session (morning of 13 November 2006) had the purpose of providing participants with a general framework of the scientific themes related to explosive volcanism and volcanic hazards in the context of IODP and ICDP research priorities, with examples of already existing projects based on scientific drilling.

Outstanding examples of ongoing projects dedicated to scientific drilling at calderas and/or active volcanic areas were represented by the Long Valley (CA, USA) and the Iceland Rift. Both these drilling projects have dealt with high temperature gradients and complex geothermal systems, thus offering good examples for the physical and chemical conditions that can be encountered in an active volcanic area like the Campi Flegrei, at depth.

The Chicxulub ICDP-IODP Projects, Mexico represented a relevant case history of joint IODP-ICD project aimed at the reconstruction of the Late Cretaceous Chicxulub meteoritic impact crater, that also displays morphologic analogies, in terms of morphologic convergence, with large volcanic craters.

Other lectures have illustrated examples of the importance of well-logging (of relatively deep holes from Canary Islands), as well as the need of very high quality reflection seismic site survey (from the Mid Ocean Ridge System, Leg 169 and the Baltic Sea), in order to calibrate drilling targets with adequate confidence.

The last part of the plenary session was dedicated to the general geological setting of the Campi Flegrei Caldera and the summary results of a previous deep drilling project that was conducted during the 70's through the early 80's by the Italian company for the electric energy, in order to explore the geothermal potential of the Campi Flegrei onland.

The field trip (afternoon of 13 November 2006) consisted of two stops (Stop 1: Coroglio, and Stop 2: Torregaveta).

Stop 1: Coroglio, at relatively short distance form the Congress Centre of Città della Scienza. The aim of the stop is to show a relatively representative section of the Neapolitan Yellow Tuff Formation cropping out in the Posillipo cliff.

The Neapolitan Yellow Tuff is the product of a series of pyroclastic flows emplaced during a major eruption and collapse of the Campi Flegrei Caldera that occurred about 15 ky B.P. Most of the pyroclastic rocks that constitute this stratigraphic unit underwent a significant early diagenesis and cementation by silicate neoformation (like the Zeolite) which also gives the typical yellowish color to the rock. The Neapolitan Yellow Tuff Formation reaches a thickness of several tens of meters (in the area of the town of Naples). A large part of this formation, along with a half of the Caldera structure itself, lie offshore beneath the Late Quaternary deposits of the Naples Bay.

Stop 2: Torregaveta, located at the WSW rim of the Campi Flegrei Caldera. Here at the Torregaveta cliff are exposed the oldest stratigraphic levels associated with the Campania Ignimbrite Formation. The Campania Ignimbrite is made up by a series of mostly ignimbritic units, that accompanied a major eruption and collapse of the Campi Flegrei Caldera about 40 ky B.P. The products of Campania Ignimbrite formation are spread over a large area that encompasses the whole Campania region of south Italy. Distal ashes associated with this eruption can be found as far as central Asia.

Researchers have proposed different structural controls on the eruption that originated the Campania Ignimbrite Some authors proposed a fissural eruption mechanism, controlled by pre-existing faults located north of Campi Flegrei for the emplacement of Campania Ignimbrite (Di Girolamo, 1970; Barberi et al., 1978; De Vivo et al., 2001). Conversely, many researchers, on the basis of outcrop data, subsurface data, gravimetry, and seismic tomography consider the Campi Flegrei and Northern Naples Bay as a classic plate (piston) caldera associated with the large-volume eruptions of the Campania Ignimbrite (Rosi and Sbrana, 1987; Orsi et al., 1996; Zollo, 2004) and the Neapolitan Yellow tuff (e.g. Orsi et al., 1996; Scarpati et al., 1993) (Fig. 2). Other authors support the idea that Campi Flegrei is merely a volcanic complex, which location is likely controlled by tectonic structures and even question the existence of a caldera sensu stricto (Milia and Torrente, 1999; Bellucci et al., 2006).

The ESF Magellan thematic session lasted two days and included a first day of invited presentations and a second day of Working Groups meetings, discussion and reports.

Invited presentations (14 November 2006) focused on the following topics:

- *Tectonic and volcanologic framework of the Tyrrhenian continental margin*
- *Structure and evolution of the Campi Flegrei Caldera*
- *Isotopes and geochronology methods for volcanic rocks*
- *Marine tephrostratigraphy of the western Mediterranean*
- *Case histories from other Mediterranean and extra-Mediterranean volcanic regions*

Working Groups discussion and reports (15 November 2006) mostly evolved around the joint IODP-ICDP Campi Flegrei drilling projects and the ways to improve integration and complementarity between the two. Particularly, it was agreed that the two components should form a single, coherent project and, at same time, each of them should keep its autonomy, peculiarity, and internal consistency.

Following a general discussion it was proposed that the IODP - Campi Flegrei project should mostly concentrate on materials, geometries and other time/space parameters associated with relatively shallow structural levels, while the ICDP should rather concentrate on physical-chemical processes, the rock-fluid properties and the geothermal system at depth.

Particularly it was concluded that the IODP pre-proposal #671 "Drilling through an active caldera, offshore Campi Flegrei, eastern Tyrrhenian margin (CAFE Project)" (http://www.iodp-mi-sapporo.org/active.html) should be revised by properly addressing the following key issues/questions:

1) It should be made clear why the Campi Flegrei Caldera Caldera is an important drilling target compared to other calderas. For example, the revised preliminary proposal should indicate explicitly what can be learned at Campi Flegrei that cannot be achieved by drilling other well-studied terrestrial calderas such as Long Valley, Aso, or others. It could be also stated, for instance, that the Campi Flegrei has an important peculiarity that makes it a unique case in the world. This caldera is characterized, in fact by the highest recorded ground deformation, not immediately followed by eruptions. In addition the Campi Flegrei volcanic area was inhabited since at least the bronze age and has a long archaeological and historical record of activity.

2) Is it really necessary to drill the submarine portion of the caldera to achieve the key scientific objectives ? In other words, a fundamental e question is: what can be learned from already existing cores, and what results cannot be accomplished by drilling on land?
First of all, it is to be noted that previous drillings realized by the AGIP/ENEL consortium some decades ago didn't explore the caldera fill deposits in detail. Moreover, drilling sites couldn't be located according to specific targets, bur rather according to the available space for drilling operations in a highly urbanized area, and no drilling site could be located neither in the center of the caldera nor in its eastern part.
Secondly, only an offshore drilling would allow: a) the reconstruction of a virtually complete stratigraphic record, which is substantially missing onland; b) the drilling of the centre (and the presumed resurgence area of the Caldera; c) the reconstruction of the south-eastern rim of the caldera; d) the recovery of distal marine tephra which are relevant to reconstruct the dispersal areals of fall-out deposits.

3) What can be learned from offshore drilling regarding the cause of ground deformation and the origin of the caldera? Since the centre of the Campi Flegrei caldera lies beneath the seafloor of the Pozzuoli bay (northern part of the Naples Bay), offshore drilling will likely reveal the structure and stratigraphy of the post collapse resurgence-type seafloor deformation. The offshore location of proposed drill sites will make possible a detailed stratigraphic reconstruction of the sin-deformational history of the upper Quaternary deposits. This will provide, in turn, solid constraint in order to understand and decipher the seafloor deformation associated with caldera resurgence phenomena. Moreover, the offshore recovery of a relatively complete stratigraphic succession of the caldera fill, down to the caldera floor will likely provide a precious record of the caldera collapse and post collapse evolution.

4) What is the purpose of deploying new logging tools? There was a general consensus among workshop participants that at least two drillholes should be located with the scope of realizing both logging-while-drilling and long-term borehole monitoring targeted for various physical/chemical parameters. In addition to the IODP routine logging tools it has been suggested the use of borehole observatories like downhole broadband seismic stations, equipped with newly developed generations of opto-electronic strain-sensors and/or advanced CORK systems that incorporate multiple seals allowing zoned measurements of *in situ* physical, chemical and biological properties, has been planned for at least two holes of the proposed drilling transect. HYACE-type coring system (Hyperbaric -Gas Hydrate- Autoclave Coring Equipment) may be also adopted in order to sample and maintain cores at *in situ* temperatures and pressure. The use of this tool may be crucial to study the microbiological content and the physical-mechanical properties of rock samples.
The installation of long-term borehole observatory may be crucial for the understanding of the evolution of a restless caldera like the Campi Flegrei.

5) How will drilling results allow us to distinguish among the different hypotheses presented in the literature for the origin of the caldera? The majority of participant agreed that the most accredited hypotheses for the origin of the caldera is the "nested" or "piecemeal" model (e.g. Orsi et al., 1996; Scarpati et al., 1993; Lipman, 2000). This model should be tested by a land-sea drill transect across the Campi Flegrei that may provide the necessary information to unlock the geometry of the caldera itself, and the stratigraphic record associated with the different elements of the caldera structure. These data appear to be absolutely necessary in order to reconstruct the evolution of the Campi Flegrei Caldera within the context of the eastern Tyrrhenian basin margin.

Criteria for IODP drill sites selection

Among the outcomes of the general discussion, there was a proposal for a revised location of IODP drill sites off the Bay of Naples which can be summarized as follows:

- site CF-01 caldera centre, in order to penetrate the structural floor of the NYT caldera (1.5-2. km) and base of the sample the tectono-stratigraphic interval likely involved in the late stage caldera resurgence.

- site CF-02 additional, (optional, or alternate) along-transect site within the NYT caldera collapse, in order to drill the caldera fill at site of minor stratigraphic thickness (0.8 - 1.0 km approx.)

- site CF-03 intended to drill the hypotetical external rim of the CI caldera and penetrate a relatively complete stratigraphic section (Monte di Procida-type, eventually including old domes or intrusions) at shallower depth (0.6 - 0.8 km approx)

- site CF-04 drill site located right outside the CI caldera hypotetical collapse, in order to sample the non-coollapsed stratigraphic sequence (0.8 -1.0 km)

- site CF-05 intended to penetrate a reference Quaternary stratigraphic (tephro-stratigraphic) section at median distance and relatively undisturbed location. The site has been selected in order to drill through 1 km of Quaternary sediments.

- sites CF-06/08 relatively shallow drill holes (0.4 - 0.6 km) planned at distal site locations, in order to get the signature of major explosive events (a "high-frequency filtered" stratigraphic record of ash layers) of the entire Campania volcanic district. This drill sites would also yield information on large scale (regional) dispersal areas that are crucial for the reconstruction of the dynamics and evolution of eruptive events (added regional value).

Objectives of a joint IODP-ICDP drilling project dedicated to the Campi Flegrei Caldera

Following the reports of Working Groups leaders from the ICDP thematic sessions of 14 and 15 November, 2006, it was concluded that a strictly coordinated IODP-ICDP drilling project dedicated to the Campi Flegrei Caldera should be setup. Accordingly, the following general objectives have been identified:

1) Sampling, dating and geochemical analyses of continuous geological sections, will allow a reconstruction of the volcanic history since well before the pre-caldera activity. This will be particularly important for the IODP component, because the off-shore volcanic history of the Campi Flegrei Caldera is poorly known, except for relatively shallow stratigraphic levels.

2) Reconstruction of the substructure composition, rehology, thermal state and elastic parameters. This part will be essentially developed by the ICDP component. It will allow to identify the depth of transition from brittle to ductile rehology and, from the thermal state at depth, it will permit a reliable inference of the depth of the shallowest magma chamber. In particular, the direct knowledge of the rock formations, just below the collapsed structure, will allow to understand the nature of high velocity anomalies detected by seismic

tomography, which could indicate intrusive rocks (mushy magma chamber). Such inference would be of leading interest to afford the general problem of location, rehology and thermal state of shallow magma chamber at calderas.

3) Reconstruction of the geothermal system, pressure, temperature and hydrologic rock parameters. The accurate reconstruction of the permeability, porosity, fracturing of the shallow geothermal system will allow to build well constrained model of flow circulation and of pressure/temperature changes induced by changes in thermal input from the shallow magma chamber. It will then completely clarify the important role played by indirect magmatic/geothermal system interaction in the genesis of unrest episodes, typical of many calderas, characterised by large consecutive phenomena of uplift and subsidence, often accompanied by intense seismicity, and their relation with eruptive episodes. It will also allow to make important inference on the mechanisms of direct magma/water interaction, which strongly characterizes the eruptive style in the area.

4) Stress determination at depth. There is growing evidence that volcanotectonic and geophysical processes, to a large degree, depend on local stresses, namely stresses that may change abruptly from one mechanical layer in the volcano to another. Since the great majority of eruptions are supplied through magma-driven fractures, and caldera ring faults are shear fractures, viable models on forecasting caldera slip and volcanic eruptions must be based on a thorough understanding of the stress conditions inside volcanoes. In particular, hydrofracture stress measurements in drill holes into the Campi Flegrei area should give us information on the state of stress in the volcano that would allow us to interpret the surface deformation and other unrest features in terms of realistic models.

5) Gas geochemistry study. It will provide important insights into the geology of the Campi Flegrei reservoir. Information on deep gases composition, and gas load of the pore/formation fluids and the drill mud, not available at the Campi Flegrei Caldera, will be obtained through continuous on-line monitoring of mud gas composition as well as temperature, electrical conductivity, pH and Eh values of the drilling mud. In addition, the gases liberated during the production test will be analyses in real-time, as well. Gases dissolved in the drilling mud will be extracted with a degassing device mounted on the shale shaker screens. Quantitative analysis the gas will be run into an automatic gas mass spectrometer (N_2, O_2, Ar, He, CO_2, H_2 and CH_4), gas chromatograph (CH_4, C_2H_6, C_3H_8 and C_4H_{10}) and radon (^{222}Rn) spectrometer installed in a laboratory container very close to the drilling site. Further the continuous gas measurements conducted at different depths on several species (CO_2, H_2O, NH_3, CH_4) will be performed with new technologies based on different laser spectrometers based on a semiconductor laser emitting around 2 μm and with a spectrometer able to measure in continuous the $\delta^{13}C$.

6) Organic geochemistry. This will provide the opportunity to explore a microbial ecosystem in the deep biosphere in a terrestrial setting related to a complex hydrothermal system such us the Deep Drilling site at Bagnoli. The discovery of bacteria in such deep terrestrial environments contest will provide insight on the presence of ubiquitous and largely unexplored so-called deep biosphere on Earth. Therefore Deep drilling at Campi Flegrei will allow microbiologists and geologists to better constrain the high bacterial populations present at least to hundreds of metres depth.

7) New opto-electronic borehole monitoring. Further during the project will be designed and tested prototype of an efficient multiparametric monitoring system for strain and temperature monitoring, in addition to the already mentioned gas geochemistry. The system will take advantage from newly developed prototypes of fibre-optics sensors. The system, entirely cabled in fibre optics, will consist of strain and temperature sensors in fibre optics using the 'Bragg's gratings' principle assembled as deformation, seismic and acoustic sensors, in addition to laser sensors for gas spectrometry. The system will constitute an advanced prototype system for borehole monitoring of unrest phenomena at Campi Flegrei Caldera.

3. ASSESSMENT OF THE RESULTS AND IMPACT OF THE EVENT ON THE FUTURE DIRECTION OF THE FIELD

Future IODP research and science planning calls for a more expansive, ambitious approach to ocean drilling to study the many active geologic processes, such as earthquakes, landslides, volcanic eruptions, and centennial to decadal sea-level changes that will affect the future of humankind on Earth in the next centuries. Offshore drilling at specific sites such as Eastern Caribbean – Lesser Antilles (Montserrat volcano), off the Japanese volcanoes (e.g. Mt. Unzen, or Tokyo area near Mount Fuji) or the Campi Flegrei Caldera near Naples, is likely to provide a significant source of information to substantially improve our understanding of the interaction between volcanism and large-scale tectonics, as well as our capability to predict the onset, styles of evolution, and cessation of volcanic eruptions.

Until recently, relatively limited attention has been paid by the IODP community to geohazards. In particular major issues and /or areas of geohazards are not significantly represented in existing IODP proposals, notwithstanding the clear message from many European Funding Agencies that geohazards assessment is among the first priorities of several countries worldwide. This ESF-ICDP supported workshop was among the first efforts of the European community to assess volcanic hazard within the context of IODP and is likely to be a reference component for future ECORD initiatives including the implementation of the IODP-Initial Science Plan (ISP) and the eventual development of mission proposals focused on "geohazards".

The event has been among the first European efforts to assess volcanic hazard within the context of IODP and is likely to be a reference for future initiatives towards an implementation in the IODP-Initial Science Plan and the eventual development of hazard mission themes. Participants provided evidence that the peculiar setting and features of the partially submerged Campi Flegrei Caldera makes it an ideal natural laboratory for future joint ICDP-IODP research.

Although the present ESF-Magellan workshop was almost entirely dedicated to the Campi Flegrei Caldera, the outcomes of the associated discussion should be framed in the wider context of volcanic hazard, or more in general, of *geohazards*. Another initiative associated with geohazards was the other ESF Magellan Workshop Scientific Ocean drilling behind the assessment of geo-hazards from submarine slides, (Barcelona, 25-27 October 2006). Both these Magellan workshops may represent a reference for the future IODP-IMI workshop on Geohazards scheduled for this year, in the USA.

The main results of the Workshop can be summarized as follows:

1) Volcanic hazard has been recognized as a prominent issue in geohazards,

2) The Campi Flegrei Caldera drilling project was identified as a candidate for a fully integrated IODP-ICDP drilling proposal. The IODP component should be focused mostly on materials, geometries and other time/space parameters associated with relatively shallow structural levels, while the ICDP component should rather concentrate on physical-chemical processes, the rock-fluid properties and the geothermal system at depth.

3) The understanding of geohazards should be integrated among scientific priorities of the IODP Initial Science Plan

4) Geohazards may represent, as a whole, an adequate target for an IODP Mission proposal.

Future actions associated with the outcomes of the workshop include the following:

1) Submission of a revised ICDP proposal dedicated to the drilling of the Campi Flegrei Caldera by 15 January 2007

2) Submission of a revised IODP proposal dedicated to the drilling of the Campi Flegrei Caldera by 1 April 2007

3) Submission of an ESF – TOPO-Europe Outline Proposal dedicated to the study of active ground deformation at Campi Flegrei, by May 2007.

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4. FINAL PROGRAMME OF THE WORKSHOP

Monday, 13 November, 2006

ICDP workshop & ESF Magellan Workshop Series Joint Sessions
(Conference Centre "Città della Scienza" Via Coroglio, 57)

09:00 – 09:20 Welcome
09:20 – 09:50 Introduction (**G. De Natale**, **M. Sacchi**)
09:50 – 10:10 ICDP Activity and Projects (**U. Harms**)
10:10 – 10:30 Drilling opportunities in IODP (**D. Evans**)
10:30 – 10:40 Discussion

10:40 – 10:55 Coffee Break

ICDP-IODP drilling projects: Learning from experience
10:55 – 11:15 The LVE-ICDP Project at Long Valley caldera (USA) (**D. Hill**)
11:15 – 11:35 The IDDP-ICDP Project at Icelandic volcanic rifts (**G. O. Fridleifsson**)
11:35 – 11:55 High Resolution Structural Imaging in Shallow and Deep Water – Recent Examples from a Mid Ocean Ridge System (Middle Valley; Leg 169) and the Baltic Sea (**V. Spiess**)
11:55 – 12:15 The Tenerife (Canary Island) Drilling Project (**M. Jurado**)
12:15 – 12:35 The Chicxulub ICDP-IODP Projects (**J.U. Fucugauchi**)

The Campi Flegrei caldera: Previous drilling results and volcanological setting
12:35 – 12:55 The magmatic and hydrothermal system at Campi Flegrei, as inferred from AGIP deep geothermal wells (**A. Sbrana**)
12:55 – 13:15 Volcanological setting of Campi Flegrei (**G. Mastrolorenzo,** L. Pappalardo)
13:15 – 13:30 Discussion

13:30 – 14:30 Lunch Break

ESF field-trip to the Campi Flegrei Caldera (Field trip leaders: **C. Scarpati, A. Perrotta**)

14:30 – 15:30 Stop 1: Coroglio
15:30 – 17:00 Stop 2: Torregaveta

Tuesday, 14 November, 2006

ESF Magellan Workshop Series Session
(University of Napoli Federico II - Mineralogy Museum, Via Mezzocannone, 8)

09:00 – 09:20	Welcome
09:20 – 09:40	Introduction and aims of the ESF Magellan Workshop session (**M. Sacchi**)
09:40 – 10:00	Structure and dynamics of the Campi Flegrei Caldera: a site for research drilling (**G. Luongo**)
10:00 – 10:20	Phlegrean Calderas (**C. Scarpati**, A. Perrotta, P. Cole)
10:20 – 10:40	Calderas in the Azores and their formation **(P. Cole)**
10:40 – 11:00	Discussion
11:00 – 11:20	Coffee Break
11:20 – 11:40	The role of mantle processes for the closure of Atlantic-Mediterranean marine gateways and the desiccation of the Mediterranean in the Late Miocene (**S. Duggen**)
11:40 – 12:00	The late Pleistocene pyroclastic deposits of the Campanian Plain: new insights on the explosive activity of Neapolitan volcanoes (**R. Sulpizio**)
12:00 – 12:20	Petrological evolution of the Campi Flegrei (**L. Fedele**, V. Morra)
12:20 – 12:40	Discussion
12:40 – 13:40	Lunch Break
13:40 – 14:00	Sr, Nd, and Pb isotopes in volcanic rocks of the Southern Italian Region: contribution to their characterisation and genesis. (**S. Conticelli**, E. Boari, R. Avanzinelli, S. Tommasini)
14:00 – 14:20	Precision Ar/Ar geochronology of onshore and offshore dating of Campi Flegrei products (**A. T. Calvert**)
14:20 – 14:40	Marine tephrochronology in the Tyrrhenian and Adriatic Seas (**M. Paterne,** G. Siani, R. Sulpizio)
14:40 – 15:00	Discussion
15:00 – 15:20	Coffee Break
15:20 – 15:40	Tectonic evolution of the Tyrrhenian margin and volcanism in the Neapolitan area (**M. Mattei**, C. Faccenna)
15:40 – 16:00	Stratigraphic architecture off the Campi Flegrei. The influence of volcanism and tectonics (**A. Milia**, M. Torrente)
16:00 – 16:20	Seafloor base maps, geological features and volcanic hazard assessment: examples from the Bay of Naples, Campania, Southern Italy (**C. Violante,** G. de Alteriis, E. Esposito)
16:20 – 16:40	Tephrostratigraphy of Naples and Salerno bays: new insights into the volcanic activity of the Campania continental margin (**D. Insinga**, A. T. Calvert, F. Molisso, V. Morra, M. Sacchi)
16:40 – 17:00	Discussion and organization of Working Groups (**M. Sacchi**)
20:00	Social Event

Wednesday, 15 November, 2006

ESF Magellan Workshop Series Session

(University of Napoli Federico II - Mineralogy Museum, Via Mezzocannone, 8)

09:00 – 11:00 Working Groups Meetings

11:00 – 11:20 Coffee Break

11:20 – 13:30 Working Groups Meetings

13:30 – 14:30 Lunch Break

14:30 – 16:30 Presentation and discussion of Working Groups results

16:30 – 17:00 Coffee Break

17:00 – 18:00 Summary of Working Groups results and recommendations by WG leaders

Tab. 1. Synopsis of the workshop programme

ESF - Magellan Workshop Series: Drilling through an active caldera, offshore Campi Flegrei, Eastern Tyrrhenian margin" (13-15 November, 2006 Napoli, Italy)			
Day	**Place**	**Time**	**Programme**
Monday 13 November	Conference Centre: Città della Scienza Via Coroglio, 57	08:30 – 14:30	ICDP workshop - ESF Magellan Workshop Series Joint Sessions
	Campi Flegrei	14:30 – 17:00	ESF Field trip
Tuesday 14 November	University of Napoli Federico II Mineralogy Museum Via Mezzocannone, 8	09:00 – 17:20	ESF Plenary Session
Wednesday 15 November		09:00 – 18:00	ESF Working Groups

Appendix 1. List of Speakers

1.	**Calvert Andrew T.**	United States Geological Survey (USGS), Menlo Park, CA, USA
2.	**Cole Paul**	University of Coventry, Coventry, UK
3.	**Conticelli Sandro**	University of Firenze, Firenze, Italy
4.	**De Natale Giuseppe**	Istituto Nazionale di Geofisica e Vulcanologia (INGV), Napoli, Italy
5.	**Duggen Svend**	IFM-GEOMAR - Leibniz Institute for Marine Sciences, Kiel, Germany
6.	**Evans Dan**	ECORD Science Operator (ESO) - British Geological Survey, Edinburgh, UK
7.	**Fedele Lorenzo**	University of Napoli Federico II, Naples, Italy
8.	**Fridleifsson Gudmundur O.**	ISOR - Iceland Geosurvey, Reykjavík, Iceland
9.	**Fucugauchi Jaime U.**	National University of Mexico (UNAM), Mexico City, Mexico
10.	**Harms Ulrich**	GeoForschungsZentrum Potsdam, Potsdam, Germany
11.	**Hill David P.**	United States Geological Survey (USGS), Menlo Park, CA, USA
12.	**Insinga Donatella**	Institute for Coastal Marine Environment (IAMC), CNR, Napoli, Italy
13.	**Jurado María J.**	Institute of Earth Sciences “Jaume Almera”, CSIC, Barcelona, Spain
14.	**Luongo Giuseppe**	University of Napoli Federico II, Naples, Italy
15.	**Mastrolorenzo Giuseppe**	Istituto Nazionale di Geofisica e Vulcanologia (INGV), Napoli, Italy
16.	**Mattei Massimo**	Università degli Studi Roma Tre, Roma, Italy
17.	**Milia Alfonsa**	Institute for Coastal Marine Environment (IAMC), CNR, Napoli, Italy
18.	**Paterne Martine**	LSCE Laboratoire CNRS-CEA, Gif sur Yvette, France
19.	**Sacchi Marco**	Institute for Coastal Marine Environment (IAMC), CNR, Napoli, Italy
20.	**Sbrana Alessandro**	University of Pisa, Pisa, Italy
21.	**Scarpati Claudio**	University of Napoli Federico II, Naples, Italy
22.	**Siani Giuseppe**	Université de Paris-Sud, Orsay, France
23.	**Spiess Volkhard**	University of Bremen, Bremen, Germany
24.	**Sulpizio Roberto**	University of Bari, Bari, Italy
25.	**Violante Crescenzo**	Institute for Coastal Marine Environment (IAMC), CNR, Napoli, Italy

Appendix 2. List of other Participants

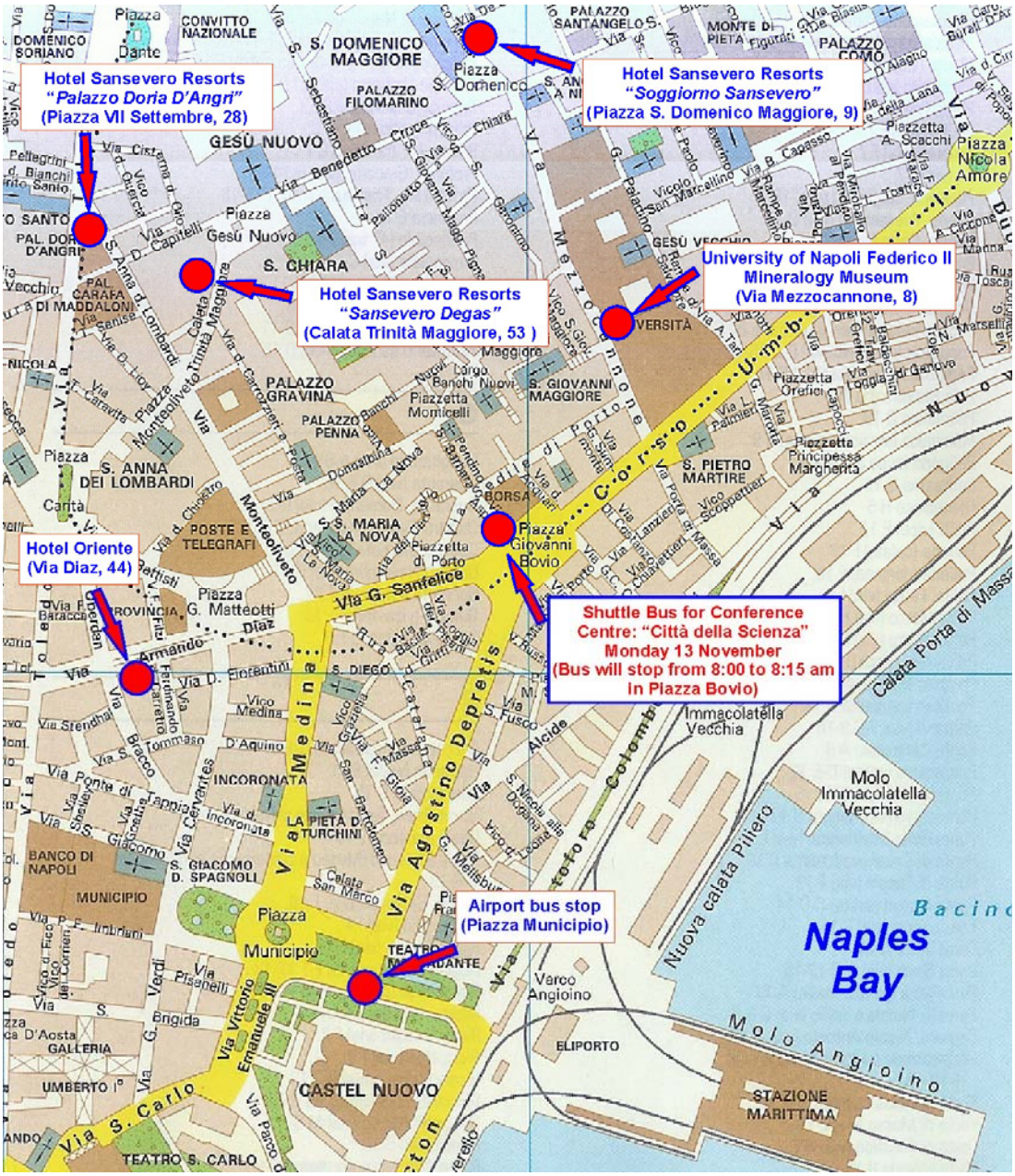
1.	**Conforti Alessandro**	Institute for Coastal Marine Environment (IAMC), CNR, Napoli, Italy
2.	**de Alteriis Giovanni**	Institute for Coastal Marine Environment (IAMC), CNR, Napoli, Italy
3.	**Esposito Eliana**	Institute for Coastal Marine Environment (IAMC), CNR, Napoli, Italy
4.	**Faccenna Claudio**	Università degli Studi Roma Tre, Roma, Italy
5.	**Fernandez Pelaez Miguel A.**	University of Granada, Granada, Spain
6.	**Fulignati Paolo**	University of Pisa, Pisa, Italy
7.	**Grifa Celestino**	University of Napoli Federico II, Naples, Italy
8.	**Herruzo Garcia Juan M.**	University of Granada, Granada, Spain
9.	**Lustrino Michele**	University of Rome La Sapienza, Rome, Italy
10.	**Marianelli Paola**	University of Pisa, Pisa, Italy
11.	**Marsella Ennio**	Institute for Coastal Marine Environment (IAMC), CNR, Napoli, Italy
12.	**Mata Garrido Javier**	University of Granada, Granada, Spain
13.	**Melluso Leone**	University of Napoli Federico II, Naples, Italy
14.	**Molisso Flavia**	Institute for Coastal Marine Environment (IAMC), CNR, Napoli, Italy
15.	**Morra Vincenzo**	University of Napoli Federico II, Naples, Italy
16.	**Perrotta Annamaria**	University of Naples Federico II, Naples, Italy
17.	**Porfido Sabina**	Institute for Coastal Marine Environment (IAMC), CNR, Napoli, Italy
18.	**Raspini Arturo**	Institute for Coastal Marine Environment (IAMC), CNR, Napoli, Italy
19.	**Siegel Coralie**	University Joseph Fourier, Grenoble, France
20.	**Torrente Maurizio**	Sannio University - Faculty of Science, Benevento, Italy

Appendix 3. Arrival and Logistics

How to get to Naples downtown

- From Naples airport (Capodichino): Airport bus 'ALIBUS' (every 20 minutes, tickets cost €3 and can be purchased on board) connects the airport to Naples downtown (Piazza Municipio). All selected Hotels are at a short walk from Piazza Municipio. Taxis cost approx €25 but may be considerably more when the traffic is bad (as it frequently is).

- From the main station Napoli Centrale (or Napoli Piazza Garibaldi, same location, underground): Take bus R2 stop in Piazza Municipio.



Hotel Sansevero Resorts
"Palazzo Doria D'Angri"
(Piazza VII Settembre, 28)

Hotel Sansevero Resorts
"Soggiorno Sansevero"
(Piazza S. Domenico Maggiore, 9)

Hotel Sansevero Resorts
"Sansevero Degas"
(Calata Trinità Maggiore, 53)

University of Napoli Federico II
Mineralogy Museum
(Via Mezzocannone, 8)

Hotel Oriente
(Via Diaz, 44)

Shuttle Bus for Conference Centre: "Città della Scienza"
Monday 13 November
(Bus will stop from 8:00 to 8:15 am in Piazza Bovio)

Airport bus stop
(Piazza Municipio)

Fig. a. Location of selected Hotels and relevant places in Naples downtown

List of Selected Hotels

Hotel Oriente
Via A. Diaz, 44
80134 Napoli
http://www.thi.it/eng/benvenuto.asp?id=9
Phone +39 081 551 21 33
Fax +39 081 551 49 15

Hotel Sansevero Resorts
"Palazzo Doria D'Angri"
Piazza VII Settembre, 28
80134 Napoli
http://www.albergosansevero.it/pal_ing.html
Phone. +39 081 790 10 00
Fax +39 081 790 10 00

Hotel Sansevero Resorts
"Soggiorno Sansevero"
P.za S.Domenico Maggiore, 9
80134 Napoli
http://www.albergosansevero.it/sog_ing.html
Phone. +39 081 790 10 00
Fax +39 081 790 10 00

Hotel Sansevero Resorts
"Sansevero Degas"
Calata Trinità Maggiore, 53
80134 Napoli
http://www.albergosansevero.it/degas_ing.html
Phone. +39 081 790 10 00
Fax +39 081 790 10 00

Meeting Places and Logistics

Monday 13 November 2006

- **Meeting Place:** Conference Centre "Città della Scienza" Via Coroglio, 57.

- **A shuttle bus** leaving from Piazza Bovio (See Fig. 1) will accompany workshop participants to Città della Scienza. The bus will stop in Piazza Bovio from 8:00 to 8:15 a.m.

Tuesday 14, November and Wednesday 15, November 2006

- **Meeting Place:** University of Napoli Federico II - Mineralogy Museum, Via Mezzocannone, 8, 2nd floor (if going up by elevator press 3rd floor and then walk down one flight of stairs)

- The **Mineralogy Museum** is at convenient walking distance from all the selected hotels (see Fig. a)

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