Commission on Mineral and Thermal Waters

Commission Eaux Minérales et Thermales

MINUTES
OF THE 44th ANNUAL SESSION

13th to 20th September 2015, Rome, Italy

Together with

42nd IHA Congress AQUA2015 – Hydrogeology: Back To The Future, 13th – 18th September, Rome, Italy

&

Post Congress Tour

Ischia Island – Fiuggi, Italy, 18th – 20th September

prepared by: Andy Shugg, Anna Wachowicz, Adam Porowski

According to the decision of the CMTW-IAH Meeting 2014 in Carlovy Vary, Czech Republic, **the meeting of the IAH Commission on Mineral and Thermal Water in 2015 was held in Rome, Italy.**

The meeting took place together with 42nd IAH Congress AQUA2015 from 13th to 18th September 2015 (www.iah2015.org)

The open meeting of the CMTW took place 14th September, 17:30 – 18:30 during the official IAH Commissions and Network meetings.

The business meeting of the CMTW took place during the post congress tour to Ischia Island and Fiuggi mineral waters, 18 – 20th September, 2015.

The main organizer of the CMTW meeting and post congress tour was dr Vincenzo Piscopo, Italian Chapter of IAH.

Congress AQUA 2015 summary and CMTW activity

The Congress was organized by the members of the Italian National Chapter of IAH with support of their institutions. It was held under the honorary auspices of the President of the Italian Republic and the Minister of the Environment and Protection of Land and Sea. The UNESCO International Hydrological Programme (IHP) and the Rome-based United Nations' Food and Agriculture Organization (FAO) were among scientific partners of the Congress.

The scientific part of the Congress was divided into eight thematic topics, namely:

- T1 – GROUNDWATER, FOOD AND HEALTH
- T2 – GROUNDWATER FLOW SYSTEMS BEHAVIOUR
- T3 – SUSTAINABLE USE OF GROUNDWATER RESOURCES
- T4 – URBAN AND CONTAMINANT HYDROGEOLOGY
- T5 – GROUND/SURFACE WATER: AN INTEGRATED VIEW
- T6 – GROUNDWATER GOVERNANCE AND POLICY
- T7 – GROUNDWATER MANAGEMENT IN COASTAL AREAS
- T8 – NEW TOOLS AND NEW FRONTIERS

Each topic included several sessions where oral presentations and posters were held.

The CMTW coordinated a technical session S.2.3 "Mineral and thermal waters: hydrogeology, hydrogeochemistry and sustainable management" under the topic T2; conveners – Jim Lamoreaux and Werner Balderer.

Scientific Lectures and posters by CMTW Members during the Congress, Topic T2, Session 2.3

14-Sep-2015	**Paula Maria Carreira** *(e-poster)*	PT	Isotopic signatures of hyperalkaline mineral waters as a tool to update underground flow paths (Cabeço de Vide - SE Portugal)
14-Sep-2015	**Lachassagne P.** *(e-poster)*	FR	Impact of deep fractures and ancient weathering profiles on compartmentation and functioning of hard rock sparkling natural mineral water hydrosystems. Case study of the Saint-Galmier, France, spring
14-Sep-2015	**Shugg A.** *(e-poster)*	AU	Recognition of Local and Regional Fissure based Cold Carbonated Mineral Water Flow Systems taking into account the Legacy of Hard Rock Gold Mining
14-Sep-2015	**Kaczor-Kurzawa D., Porowski A. et al. (co-authors)** *(e-poster)*	PL	REE distribution in mineral waters of the Krynica Spa, Polish Outer Carpathians: implication for water-rock interaction and mixing processes
15-Sep-2015	**Fórizs I.** *(oral speech)*	HU	Isotope hydrogeochemical study of three aquifers used for mineral water bottling in a recharge area, Hungary
15-Sep-2015	**Balderer W.** *(oral speech)*	CH	Possible influence of the Modena M 6.0 earthquake of May 20, 2012 on the fluorescence spectra of groundwater within the affected areas revealed by measurements on Bottled Mineral Water
15-Sep-2015	**Hałaj E.** *(oral speech)*	PL	Characterization of thermal waters and geothermal conditions in the Liassic formations of the Mogilno - Lodz Trough, Poland and their sustainable usability prospects
17-Sep-2015	**Marques Manuel J.** *(oral speech)*	PT	Assessment of mineral and thermal groundwater systems: the "eyes" of Geosciences
17-Sep-2015	**Wachowicz-Pyzik A.** *(oral speech)*	PL	Characteristics of hydrogeochemical parameters of thermal water from Stargard GT-2 borehole

The following workshops were organized before and during the Congress:

- WS1 – GROUNDWATER AND CLIMATE CHANGE
- WS2 – THE UNITED NATIONS WORLD WATER DEVELOPMENT REPORT, WWDR
- WS3 – SHARED VISION AND FRAMEWORK FOR ACTION FOR GROUNDWATER GOVERNANCE
- WS4 – TIPS FOR WRITING A KNOCK-OUT PAPER. MEET THE EDITOR(S) OF HYDROGEOLOGY JOURNAL – QUESTION TIME
- WS5 – ESRI ARCGIS PLATFORM FOR WATER RESOURCES
- WS6 – WATER PROJECTS IN HORIZON 2020
- WS7 – TOWARDS EUROPEAN (EN) STANDARD GUIDELINES FOR THE DESIGN AND CONSTRUCTION OF WATER WELLS

Also, several mid-week technical field trips were available for delagates, namely:

- MT1 - Hydraulic structures in Ancient Rome; Leaders: W. Dragoni and C. Cambi.
- MT2 - Volcanic aquifers of Northern Latium; Leaders: F. Lotti and E. Preziosi
- MT3 - Coastal hydrogeology of the Tiber River; Leaders: R. Mazza and and L. Mastrorillo
- MT4 - Peschiera Spring and St. Vittorino Plain in the Karst Apennine;Leaders: M. Petitta and S. Martino
- MT5 - Ninfa Spring and Pontina Plain; Leaders: G. Sappa and S. Vitale
- MT6 - Hydrothermal area of Tivoli; Leaders: F. La Vigna and A. Argentieri
- MT7 - Ancient and modern drainage of Fucino Lake and Plain; Leaders: A. Del Bon and E. Burri
- MT8 - Ferrarelle springs; Leaders: D. Ducci and V. Paolucci

CMTW Member participated in mid-week technical field trips concerning the topic of mineral and thermal waters MT2, MT4, MT6 and MT8.

CMTW Open Meeting: 14 September 2015

IAH Commissions and Network Meeting

LIST OF PARTICIPANTS

No	Name	Country	e-mail
1	LAMOREAUX, JAMES (Chairman)	USA	jlamoreaux@pela.com
2	BALDERER, WERNER (Vice Chairman)	CH	balderer@erdw.ethz.ch werner1111@msh.com bawerner@retired.ethz.ch
3	FÓRIZS, ISTVÁN	HU	forizs.istvan@csfk.mta.hu
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11	MARQUS, JOSE MANUEL	PT	Jose.marques@technico.ulisboa.pt

12	BOLTON, GRANT	AU	grant@rockwater.com.au
13	ZHU, YAN	CI, DE	yanzhuyz@gmail.com (?)

Agenda: PART I

1. Welcome of the participants and members:
2. Selection of the Protocol Secretary – regular Secretary Adam Porowski is not present.
3. Acceptance of the CMTW Minutes in Calrovy Vary, Czech Republic, 2014:
4. New information (update) from the IAH head office regarding second round of commissions & network evaluations for the next period.
5. Updated information on the process of CMTW web-site construction, development, management.
6. Information / discussion about upcoming publications form CMTW meetings:
   a) Evian and Budapest: Jim LaMoreaux and Istvan Fórizs
   b) New Zealand mineral waters: Andy Shugg and Jim Lamoreaux
   c) New publication: from CMTW meeting in Rome, 2015
   d) New publication: Petar Papić (ed), 2016 *Mineral and Thermal Waters of Southeastern Europe*, Springer.

Ad. 1.

The chairman of the CMTW, Jim Lamoreaux, welcomed all the members, presented the meeting agenda and organizational issues.

Prof. Vincenzo Piscopo presented the program of the post congress tour to Ischia Island.

Ad. 2.

Protocol Sectretary for the CMTW Open meeting – selected Anna Wachowicz

Protocol Secretary for the CMTW Business meeting – selected Andy Shugg

Ad.3.

The Minutes of the CMTW meeting in Carlovy Vary, Czech Republic, 2014, was prepared by secretary Adam Porowski. The Minutes were presented by the chairman and accepted unanimously by all members.

Ad. 4.

Chairman presented short info about Evaluation Report sent to the IAH. The report was prepared by Adam Porowski, Werner Balderer and Jim Lamoreaux. Jim has been in contact with the IAH Exec and noted that the Commission has participated in

IAH Congresses and also has published a number of publications. Therefore a report was sent ft he IAH regarding the continuation ft he Commission. It is most likely that the IAH will accept the Commission and the continuation ft he Commission activities.

Ad. 5.

Anna Wachowicz – short info about the actual state of preparation of the website, and the actual problems.

Jim LaMoreaux - short info about our efforts to highlight the case to IAH.

Jim & Anna took the opportunity to contact directly with John Chilton and Kellie, who were present at the Congress. A short discussion give the hope that all problems regarding communication between IAH technicians responsible for the server maintains and Kelly and CMWT should be solved.

The website still exists in the free of charge server with the following address: http://www.cmtw.c0.pl

Ad. 6.

Publication from Rome meeting

Vincenzo Piscopo suggests that he could compile 27 papers form Rome. Werner Balderer will also follow up. In this case Vincenzo will contact with authors. The notes from the Ischia field will be also placed on the CMTW website.

Other publication activities

a) The Budapest publication is finished with six papers edited and an additional four to make it ten papers in length. Istvan Fórizs has carried out this.
b) Evian Publication is at present only 3 – 5 papers in length. Many papers were presented during the meeting and excursion. It is possible that Patrick Lasaunge will combine these. He is also going to organize a meeting and excursion at the IAH French Meeting at Montpellier. He is a very busy.
c) Jim and Andy are going to compile the New Zealand Excursion notes. In addition provide some information on the Australian sites visited by the Commission in 1998.
d) **New publication finished:** Petar Papić (ed), 2016 *Mineral and Thermal Waters of Southeastern Europe*, Springer.

CMTW Business Meeting 2015, Ischia Island – Fiuggi, Italy

Excursion organized by: Prof Vincenzo Piscopo (Dept. Ecological and Biological Sciences) University of Tuscia, Luigi, Luigi Pianese, Italy.
Assistant Leaders Fulvio Formica, Francesca Lotti and Luigi Picanese.

<u>Schedule of the post congress tour:</u>

Sept 18th 4:30 pm: Departure from Rome (IAH conference venue) by bus to the Island of Ischia. Accommodation and dinner at Hotel Continental Ischia.

Sept 19th Business meetings of CMTW and field trip to hot springs of the Island of Ischia. The dinner will be held in a typical beach restaurant of the island.

Sept 20th 9:00 am: Departure from the Island of Ischia. Visit to the mineral springs of Fiuggi (Latium) and lunch.
4:30 pm: expected arrive in Rome (airport).

<u>CMTW Business Meeting:</u>
Date: September 19th 2015
Time: 7:00 PM
Meeting held in Hotel on the island of Ischia, Italy.
Organizer: Vincezo Piscopo, Paolo Fabbri

LIST OF PARTICIPANTS

No	Name	Country	e-mail
1	LAMOREAUX, JAMES (Chairman) *	USA	jlamoreaux@pela.com
2	BALDERER, WERNER (Vice Chairman)	CH	werner1111@msh.com bawerner@retired.ethz.ch
3	PAPIĆ, PETAR	RS	ppapic@rgf.rs
4	SHUGG, ANDREW	AU	aquaregia1@iinet.net.au
5	FÓRIZS, ISTVÁN	HU	forizs.istvan@csfk.mta.hu
6	PISCOPO, VINCENSO	IT	piscopo@unitus.it
7	SMITH, PAUL, (from Brisbane)	AU	?

* - excuses from Jim due to extreme nee to leave the meeting from personal reasons

ACCOMPANING PERSONS

No	Name	Country	
1	LaMoreaux, Nicole, Mrs *	USA	field session & cultural program
2	Balderer, Christina, Mrs	CH	field session & cultural program
3	Susan Shugg	AU	field session & cultural program
4	Marian Smith	AU	field session & cultural program

* - excuses from Nicole due to extreme nee to leave the meeting from personal reasons.

ABSENT MEMBERS

Name	Country	Member / Cand. Memb.	Absent with apologies
DOWGIAŁŁO, JAN (hon. Chairman)	PL	M	dowgian@yahoo.pl *
POROWSKI, ADAM (Secretary)	PL	M	adamp@twarda.pan.pl *
VYLITA, TOMÁŠ	CZ	M	tomasvylita@seznam.cz info@geologie-vylita.cz *
LAMOREAUX, JIM	USA	M	jlamoreaux@pela.com *
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WACHOWICZ-PYZIK, ANNA	PL	M	amwachowicz@poczta.fm *
RYBACH, LADISLAUS	CH	M	*
LOTTI, FRANCESCA	IT	CM (?)	*
VINOGRAD, NATALIA	RU	M	*
LACHASSAGNE, PATRIK	FR	M	*
KRALJ, PETER (hon. Chairman)	SLO	M	
DEÁK, JÓZSEF	HU	M	Deak47jozsef@gmail.com
FERU, ADRIAN	RO	M	
POPESCU, MARIA	GR	M	
CARELLA, ROBERTO	IT	M	
CALADO, Carlos	PT	M	
CRUZ, José Virgìlio	PT	CM	
DOTSIKA, LIANA	GR	CM	
FRANCESCHI, Michel	FR	M	
FRICKE, Michael	FR	M	
HABERMEHL, Rien	AUS	M	
HERCH, Andrea	GER	M	
IBRAGIMOVA, Irada	AZN	M	

ISSAADI, Abderrahmane	ALG	M	
LAHERMO, Pertti. W.	FIN	M	
LAING, Colin	AUS	M	
LESMO, Renato	IT	M	
MELIORIS, Ladislav	SLO	M	
MOORE, JOHN	USA	M	
PANG, Zhonghe	CHINA	M	
POUCHAN, Pierre	FR	M	
ROSENTHAL, Eliahu	IS	M	
RISLER, JEAN J.	FR	M	
SCHNEIDER, Jean	AUS	M	
SHAWKI, Abdine	ET	M	
SHTEREV, KOSTADIN	BUL	M	
TAHLAWI, Mohamed Ragaie El	EGY	M	
VERDEIL, Pierre	FR	M	
VON STORCH, KURT	GER	M	
ZUURDEG, Boudewijn	NL	M	
CUCHI, Antonio	ES	M	

Agenda Part II

7. New Regular Members (RM) & Candidate Members (CM):
    a) Petar Papic – CM from 2014, Professor of Hydrogeochemistry, Department of Hydrogeology, Faculty of Mining and Geology at University of Belgrade, Serbia.
    b) Kriang Pirarai – Senior Hydrogeologist with the Thailand Department of Ground Water Resources – voting about his Candidate Membership
    c) Louis Mangani Nyirongo – Sub Consultant Geologist at Snowy Mountain Engineering Corporation – eventual voting about his Candidate Membership ??
    d) Marian Mackovič – Engineer, Director of Mineral Water Bureau at Františkovy Lázně Spa – voting about reinstating his as Regular Member
    e) Jana Štrbački - Researcher Fellow, Department of Hydrogeology, Faculty of Mining and Geology at University of Belgrade, Serbia. – voting on her Candidate Membership;
8. Propositions of the next meetings: discussion, voting, decisions
9. Miscellaneous
    a) More efforts to attract new members – discussions and propositions;
    b) Next year, 2016: voting about new CMTW board – for new evaluation period;
    c) New activities propositions;

Ad. 7.

Regular Membership accepted for:

a) **Prof. Petar Papić** – Camdidate Member since 2014
b) **Dr. eng. Marian Macković** – reinstating membership

Candidate Membership accepted for:

a) **Jana Štrbački** - Researcher Fellow, Department of Hydrogeology, Faculty of Mining and Geology at University of Belgrade, Serbia.
b) **Kriang Pirarai** – Senior Hydrogeologist, Thailand Department of Ground Water Resources.
c) **Louis Mangani Nyirongo** – Sub Consultant Geologist at Snowy Mountain Engineering Corporation – eventual voting about his Candidate Membership ??
d) **Hose Manuel Marques** - Senior Researcher at CERENA (Centre for Natural Resources and Environment, Instituto Superior Técnico, University of Lisbon, Portugal)

Possible new Candidate Members:

- Daniel Marcos Bonoto (Brasil) – his application and CV is needed;
- Prof. Maria Contantino – Balneologist from Italy - Audiologia; (mariacostantino@firsthermal.org); She needs to be the IAH member first, then the application to CMTW can be sent.
- Paul Smith – Brisbane, Australia; His application and CV is needed;

Ad. 8.

1. Proposition 2017: together with MinWat 2017 in Portugal.

   This proposition was introduced in 2014, and corroborated in 2015 by dr Dr Jose Marques and Dr Paula Carreira, University of Lisbon, Portugal. They invited CMTW members to organize their meeting in 2017 together with this international conference.

   <u>The proposition was voted and accepted.</u>

2. Due to the fact, that we didn't have good proposition for the CMTW meeting in 2016 from our members, Adam Porowski made an internet search and presented other opportunities for organization of the meeting during the international conference or congress, namely:

   - 43th IAH Congress in Montpellier, France, 25 – 29 September 2016

- 15th Water Rock Interaction, Evora 16-21 October 2016
- IWC2016 — Water Resources In Arid Areas: The Way Forwar, Muscat, Oman,13 - 16 March 2016
- European Geothermal Congress, Strasbourg, France, 19 – 26 September 2016;
- ICHST 2016: 18th International Conference on Hydrology Science and Technology, Zurich, Switzerland, July 21 – 22 2016

The members accepted proposition of jubilee 43th IAH Congress in Monpellier as the next CMTW meeting in 2016.

3. Proposition for 2018:

- Crimea Peninsula is still possible. Dr Natalia Vinograd with collaboration with dr Elena Kayukova may present this possibility in 2016.

Ad. 9.

The members continued an important and long-lasting discussion about the development of the Commission and attraction more new and active members. All agreed that:

- the rules of membership must be reconsidered to show the real number of active members in the Commission;
- only nomination is not enough to be a Candidate Member or Regular Member of the Commission; the main factor should be participation in Commission activities.
- the Commission itself should be more active in attracting and inviting new people to collaboration.
  The members suggested considering the invitation the following professionals: (a) Dario Tedesco, Geochemistry and Volcanology Chair, Department of Environmental, Biological and Pharmaceutical Sciences and Technologies Second University of Naples, Via Vivaldi 43, 81100 Caserta, Italia; (b) Daniel Marcos Bonoto, Dep. Di Petrologa e Metalogia, Rio Claro Brasil, (c) Prof. Maria Constantino First Thermae Institute, University of Salerno, Italy (first she has to become the IAH member); (d) Paul Smith, Brisbane, Australia; (e) start collaboration with Bundesanstalt, Austria.
- the Commission should establish the closer contacts with National Chapters from different countries and ask for nominations of professionals who would like to participate in the CMTW activities.

The members agreed to prepare elections of new CMTW board in 2016 – for new evaluation period.

As a new activities: Adam Porowski proposed to seek for the EU funds to organize professional thematic courses (workshops) under the auspices of the CMTW.
He explained that he could manage this subject basing on the resources of his host institution Institute of Geological Sciences of Polish Academy of Sciences (INGPAN) which might be opened in collaboration in this matter. However, this possibility needs more consultations and will be discussed in detailed during the next meeting.
Preliminary list of members interested in this activity were performed.

IAH – CMTW 2015

Sept 18th -20th Meeting of CMWT and field trip

NEAPOLITAN VOLCANOES AND THERMAL WATERS

Leader: Vincenzo Piscopo
Associate Leaders: Fulvio Formica, Francesca Lotti, Luigi Pianese

Department of Ecological and Biological Sciences, University of Tuscia, Viterbo
IAH Italian Chapter

HYDROGEOLOGY OF THE NEAPOLITAN VOLCANOES

INTRODUCTION

The Pliocene-Quaternary volcanic areas of Central and Southern Italy constitute aquifer systems (Fig. 1) whose resources are widely used for the local drinking water supply, irrigation and industry. Mineral and thermal waters are frequently related to the volcanic aquifers and tapped for therapeutic purposes.

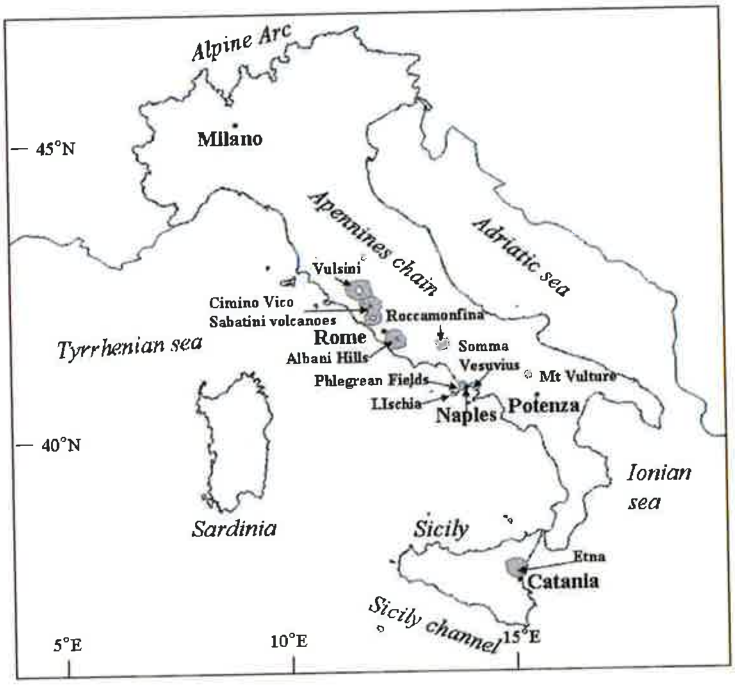

Figure 1. Location map of the volcanic aquifers in southern Italy.

The volcanoes located along the Tyrrhenian margin from Latium to Campania (Fig. 1) can be related to an orogenic tectono-magmatic association. The Roman Magmatic Province, including Vulsini, Vico, Cimino, Sabatini, Roccamonfina, Isle of Ischia, Phlegraean Fields and Somma-Vesuvius volcanoes, developed along this margin as a consequence of the intense rifting in the Pliocene-Quaternary that affected the internal Apennine Chain. In this area, the volcanic formations are mostly represented by pyroclastic products with intercalated lavas belonging to distinct magmatic series: potassic series mostly represented by shoshonitic basalts, shoshonites, latites and trachytes; high potassium series mostly represented by leucitites, leucite-basanites, phono-tephrites and leucite-phonolites.

The Mount Vulture volcano located at the easternmost border of the Apennine compressional front (Fig. 1) shows petrological analogies with the Roman Magmatic Province, although more sodic products involve an enrichment in Na-alkali silicate/carbonatite anorogenic components. The Etnean area falls in the Etna-Iblei-Sicily Channel (Fig. 1), an anorogenic volcanic province active from the Late Miocene up to Present. The Etnean volcanism initially gave rise to tholeiitic products, allowing the coexistence of tholeiitic and alkaline lavas, and subsequently hawaiite lavas.

The structural setting and related magmatic domains of these volcanic areas affect the heat flow and temperature variation with depth. A strong regional heat flow anomaly (>150 mW/m^2) concerns the peri-Tyrrhenian belt extending from Tuscany to Campania, as a consequence of a thinning of the lithosphere. In the geothermal fields of Tuscany, Latium and Neapolitan area (between the Isle of Ischia and Phlegraean Fields), very high values of heat flow have been found (from 200 up to 400 mW/m^2) with temperatures above 150-300°C at 1000 m depth.

HYDROGEOLOGY OF THE NEAPOLITAN VOLCANIC AREA

This section summarizes the primary information regarding the volcanoes' hydrogeology of the Neapolitan area, which includes the Isle of Ischia, Phlegraean Fields and Somma-Vesuvius systems (Fig. 2).

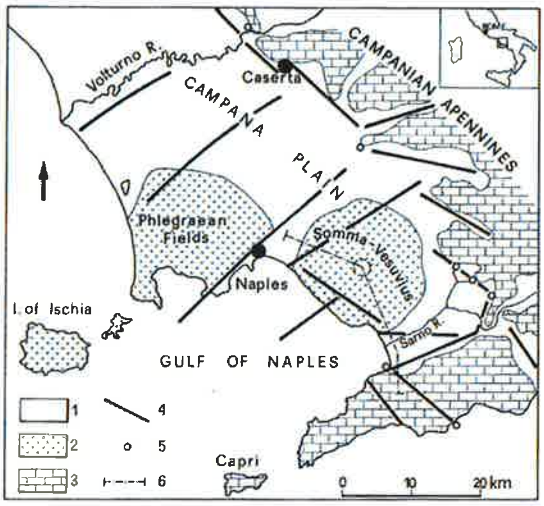

Figure 2. Neapolitan volcanic area: 1 Pyroclastic and alluvial deposits, 2 Volcanic rocks, 3 Carbonate rocks, 4 Main faults, 5 Mains springs, 6 Trace of cross-section of Fig. 6.

ISLE OF ISCHIA SYSTEM

The volcanic activity of the Isle of Ischia (787 m) developed from 150 ka to historical times, giving rise to effusive and explosive products for a thickness of around several hundred meters.

In the Isle of Ischia, it is possible to identify two distinct areas from a hydrogeological point of view, coinciding with the main volcano-tectonic structures of the island (Fig. 3).

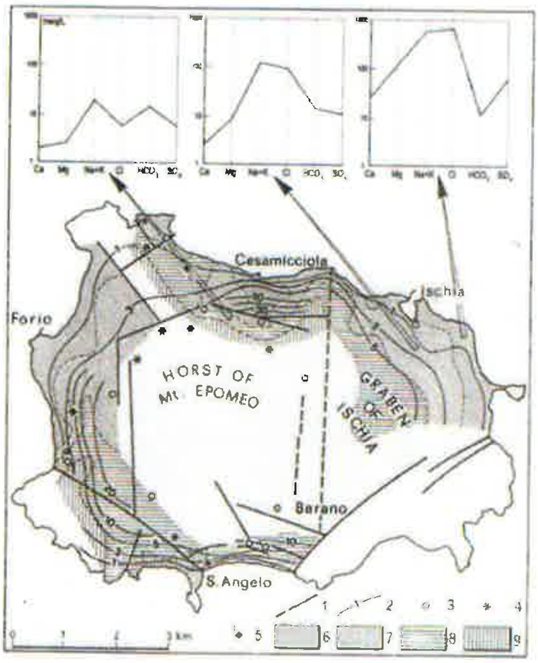

Figure 3. Hydrogeological scheme of Ischia: 1 Faults and fractures, 2 Piezometric contour lines of basal aquifer in 1996 (m asl), 3 Main springs, 4 Main fumaroles, 5 Wells 1 and 2 in Fig. 7, 6 Groundwater temperature from 20 to 40 °C, 7 Groundwater temperature from 40 to 80 °C, 8 Groundwater temperature from 60 to 80 °C, 8 Groundwater temperature from 80 to 90 °C (from Piscopo et al. 2000).

In the area of the "Ischia graben", the shallow aquifer hosts a single water-table recharged by both infiltration and saltwater intrusion. The aquifer discharges mainly into the sea. In this sector, groundwater shows Na(K)-SO_4 to Na(K)–Cl chemistry, and temperature is relatively low compared with other areas of the island (from 20 to 80°C).

In the area of "Mt. Epomeo" and its margins, the aquifer is, on the whole, less transmissive and more heterogeneous than the former. A basal water-table and several perched water-tables discharge mainly into the sea and partially into the springs (totalling 0.02 m^3/s). The numerous faults and fractures of this sector of the island may enable several overlapping aquifer layers to communicate. Salt-water recharge is also present in this area. Groundwater temperature ranges generally from 20 to 90° C with the highest temperatures (up to 100° C) found at wells or springs sited near the most recent faults, where fumaroles are also present. The perched aquifers are generally characterised by relatively less mineralised waters (EC from 5 to 10 mS/cm) of a K(Na)-HCO_3 type, while those of the basal aquifer are generally of a Na-K-SO_4-Cl type with a high salinity (EC from 10 to 60 mS/cm). Intermediate chemical compositions are found where water from different overlapping aquifers may mix.

Interaction between the aquifer and geothermal steam occurs, and hydrothermal reservoirs are recognized. Thermal waters are frequently rich in As, Mn, Se, Be, Fe and Sb, sometimes at much higher concentrations than the maximum allowable levels for drinking water.

PHLEGRAEAN FIELDS SYSTEM

The volcanic activity of the Phlegraean Fields (452 m) developed from 60 ka to historical times from numerous craters concentrated in such a small area.

The volcanites several hundred meters thick constitute an aquifer system limited by the sea on its western and southern sides and by Pleistocene-Holocene alluvial deposits of the surrounding plain.

On a large scale, an unconfined or leaky aquifer has been found with a pseudo-radial potentiometric surface and with the main flow directions orientated towards the sea and surrounding plain (Fig. 4).

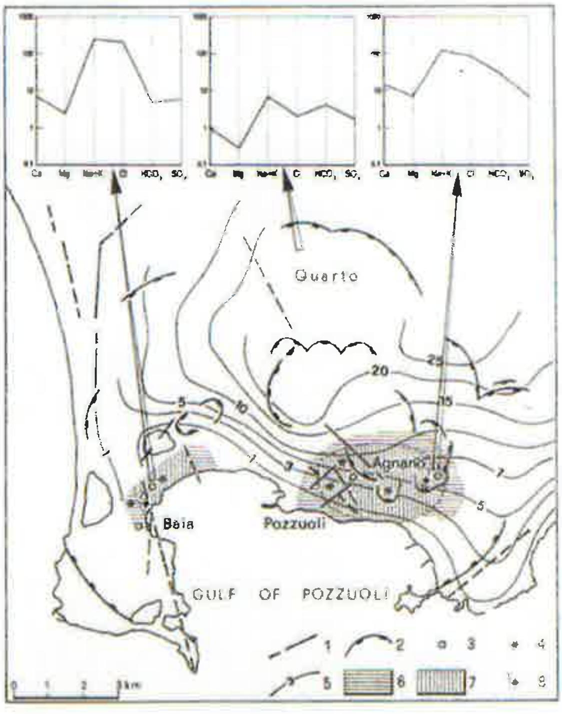

Figure 4. Hydrogeological scheme of Phlegraean Fields: 1 Faults and fractures, 2 Caldera rim, 3 Main springs, 4 Fumaroles, 5 Piezometric contour lines of basal aquifer in 1997 (m asl), 6 Groundwater temperature from 30 to 50 °C, 7 Groundwater temperature > 50 °C (from Piscopo et al. 2000).

Groundwater discharges into the sea and the springs on land. Thermal waters outflow from springs (total discharge less than 0.01 m^3/s) along the coastal zone (where fumaroles are also located). Groundwater flows also occur towards the aquifers of the surrounding plain.

The chemical composition of groundwater makes it possible to distinguish the northern sector, with K(Na)-HCO_3 and Ca(Mg)-HCO_3 waters poorly mineralised (<1 g/L) and cold (<20 °C), from the southern sector, characterised by Na(K)-Cl and Na(K)-SO_4 waters, more mineralised (up to 50 g/L) and at a higher temperature (up to 90°C). The chemical nature of the water of the latter may be traced to the mixing between a shallow meteoric component, hydrothermal fluids (both steam and thermal brines) and seawater. The rise of gas of magmatic origin (H_2S and CO_2) and of salt-water is greater in fractured zones, where preferential flow is vertical, and in the coastal zone, where the freshwater lens is less pronounced. Geothermal exploration reveals the existence of a deep saline multiple-reservoir geothermal field. In this case, waters with high temperature are also Cl-rich and show high As concentrations, up to 7,000 μg/L.

SOMMA-VESUVIUS SYSTEM

The Somma-Vesuvius (1281 m) is a strato-volcano (formed by two calderas) whose eruptive activity has alternated between effusive and explosive phases from 25 ka to historical times (Fig. 5).

The volcano constitutes an aquifers system limited by the sea on its eastern side and by Pleistocene-Holocene alluvial and pyroclastic deposits of the surrounding plain on the other sides. The substratum of the several-hundred to several-thousand meter thick volcanics is represented by low-permeability Plio-Pleistocene sedimentary units overlaying the Meso-Cenozoic carbonate deep aquifer. In the southern flank of the volcano, the carbonate aquifer lies at a lower depth (≤500 m) (Fig. 6).

The volcanic aquifer is characterised by a single radial water table, which discharge into the aquifers of the circum-Vesuvian plain and the sea (Fig. 5). It is recharged mainly by precipitation on the volcano itself and to a lesser extent by rising water from the deep carbonate aquifer. Most of the water sampled from the volcanic aquifer is of a K(Na)-HCO_3 and K(Na)-SO_4 type, with modest salinity (<1.2 g/L) and low temperature (<18 °C). In the southern sector of the Vesuvian area water sampled from wells penetrating the volcanic aquifer are of a Ca(Mg)-HCO_3 type, with a relatively high saline content (up to 9 g/L), temperature (up to 25°C) and CO_2 content (up to 2 g/L). This may be accounted for precisely by the mixing of water circulating in the shallow aquifer with water of a deep origin flowing upwards (Fig. 6).

In general, the groundwater of the Vesuvian area is strongly influenced by the input of CO_2-rich volcanic gas. On the southern slope of the volcano, the fault-controlled vertical movement of deep waters increases the concentration of Na, Cl and B in the groundwater of the shallow volcanic aquifer.

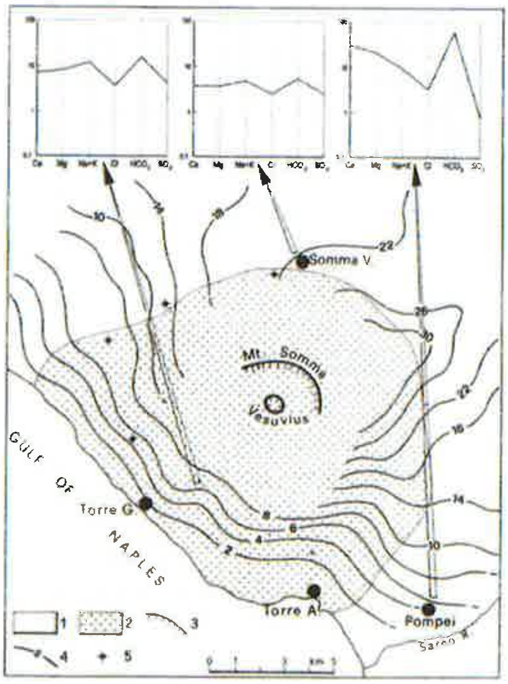

Figure 5. Hydrogeological scheme of Somma-Vesuvius: 1 Pyroclastic and alluvial deposits, 2 Pyroclastic deposits and lavas. 3 Caldera rim, 4 Piezometric contour lines of basal aquifer in 1994 (m asl), 5 Well fields (from Celico et al. 1998).

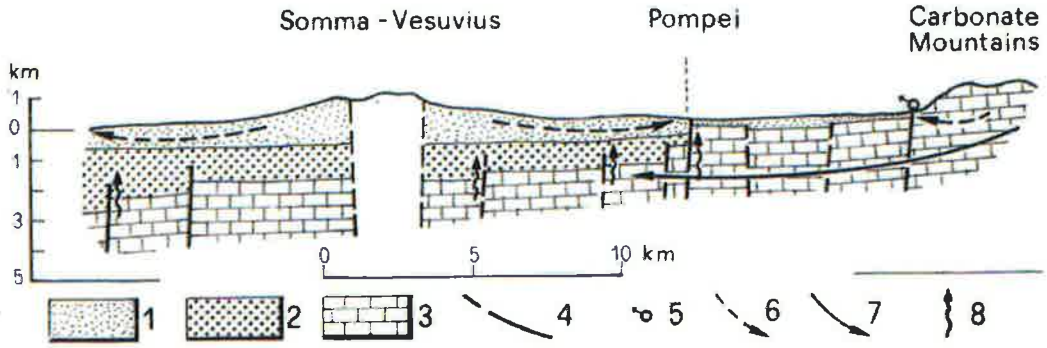

Figure 6. Schematic hydrogeological cross-section through Somma-Vesuvius: 1 Shallow aquifer, 2 Intermediate aquitard, 3 Carbonate aquifer, 4 Main faults, 5 Spring, 6 Local groundwater flow, 7 Regional groundwater flow, 8 Deep fluids rising (from Celico et al. 1998).

GROUNDWATER RESOURCES OF THE VOLCANIC AQUIFERS

The present knowledge regarding the groundwater resources of the volcanic aquifers are based on water budget estimations. The available recharge estimates were developed at the volcanic system scale and on an annual basis. The recharge estimates were generally verified through the outflow from each volcanic system considering the stream flow, the rate of discharge towards the surrounding aquifers, and withdrawals. For these latter components, the available data are frequently incomplete or discontinuous owing to the lack of an effective monitoring network.

Table 1 summarizes the results of the available estimates for each volcanic aquifer. The table shows the amount of recharge from effective infiltration, the existence of other inflows, the rate of natural outflow towards the streams and springs and surrounding aquifers or sea, and the total amount of withdrawals from the aquifer with the relative percentage used for irrigation, drinking water, industry and mineral and thermal purposes. All components are reported as the average value per unit surface.

The Isle of Ischia and Somma-Vesuvius are characterized by the other natural inflows from the sea and a deep carbonate aquifer, respectively, as can be inferred from the comparison of the infiltration recharge with the discharge amount. The latter is represented by flows towards the sea and surrounding aquifers, estimated through piezometric maps from the nineties and transmissivity values of the aquifers.

Table 1. Groundwater budget for the volcanic aquifers of Neapolitan area (from Piscopo et al. 2008).

System	SA	Recharge		Discharge (D)		Withdrawals					Level of gw development	
		In	Oth	SS	SAS	TW	Ir	D	In	MT	TW/In	TW/D
Phegraean Fields	64	7.20	*ai*	*ai*	4.48	2.72	92	*ai*	7	1	0.38	0.61
Isle of Ischia	46	5.55	*s*	0.45	8.81	1.68	39	*ai*	*ai*	61	0.30	0.18
Somma-Vesuvius	153	7.55	*da*	*ai*	4.57	5.89	34	55	10	1	0.76	1.29

SA: surface area (km^2). In: effective infiltration (L/s per km^2). Oth: other inflows (*ai* absent or insignificant, *s* sea, *da* deep carbonate aquifer). SS: streams or springs (L/s per km^2). SAS: surrounding aquifers or sea (L/s per km^2). TW: total withdrawals (L/s per km^2). Ir: irrigation (%). D: drinking water (%). In: industry (%). MT: mineral and thermal water (%).

The withdrawals are also estimated with reference to the available data of the nineties. The pumping withdrawal in the Isle of Ischia occurs during the spring-summer period — mostly for spas—through numerous wells (several hundred) distributed along the coast. Groundwater resources of the

Phlegraean Fields are used for irrigation, industry and therapeutic purposes. The numerous wells (several hundred) are scattered all over the area, and pumping occurs only occasionally throughout the year. Groundwater resources of the Somma-Vesuvius system are used mainly for the local drinking water supply, irrigation and industry.

Based on the previous estimations, the level of groundwater development of each aquifer system has been calculated as the ratios of the total withdrawals to the infiltration recharge and of the total withdrawals to the natural discharge (Table 1).

Groundwater development is high in the Somma-Vesuvius system (Table 1). A decrease of several meters in groundwater level and a downward shift of potentiometric contour lines from the general radial pattern are evident during the 1978-1993 period in the northern flank of the Somma-Vesuvius volcano where continuous pumping from well fields takes place.

Abstraction of groundwater takes place by springs, drainage galleries and wells. Certainly the wells are the most widespread system of groundwater abstraction and have a stronger effect on groundwater resources. The available data on the wells highlight yield: from 0.1 to 10 L/s for Phlegraean Fields, from 1 to 8 L/s for the Isle of Ischia, from 2 to 60 L/s for Somma-Vesuvius. Transmissivity values range between 10^{-1} and 10^{-5} m^2/s for Phlegraean Fields, 10^{-2} and 10^{-5} m^2/s for the Isle of Ischia, 10^{-1} and 10^{-4} m^2/s for Somma-Vesuvius. Storativity values of the volcanic aquifers range from 10^{-2} and 10^{-5}. These data refer to wells generally 10-200 m in depth used for public-water-supply and for private irrigation and industrial purposes. The irrigation wells are typically used for 6-8 h per day from 6 to 8 months per year. The public wells for drinking water supply are continuously used throughout the day all year round. The other types of wells (industry, spa, mineral bottling) are used with very different timing, depending on specific production.

In the volcanic areas where the rising of fluids from depths through the fractured or faulted zones occur, the water temperature and salinity increases during pumping. Particularly near the faulted zones of the Isle of Ischia, as pumping proceeds, water temperature actually increases (up to over 90°C), as well as the groundwater level, as a consequence of steam drawing up. In contrast, a decrease in water temperature in shallow aquifers has been detected in many wells along the coast when aquifer transmissivity is high, as shown in Figure 6.

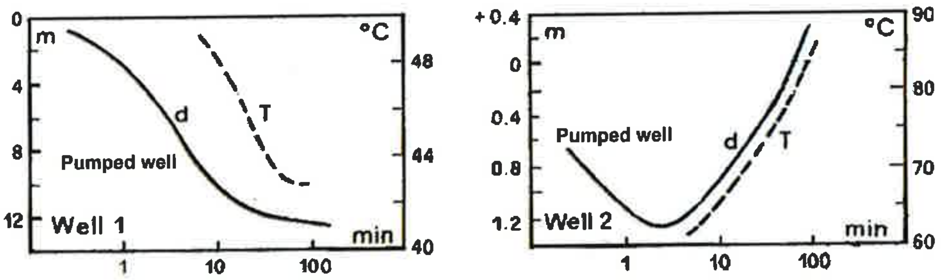

Figure 7. Drawdown (d) and water temperature (T) response of shallow well near the coast (Well 1) and deep well near faulted zone (Well 2) of the Isle of Ischia (from Celico et al. 1999).

FIELD TRIP ITINERARY

1st DAY - PHLEGRAEAN FIELDS

Phlegraean Fields, a quaternary caldera located west of the city of Naples, has been active since 47,000 yr bp. The erupted products range in composition from K-basalts to alkali-trachyte, phonolite. The two main eruptions produced widespread ash-flow deposits: the Campanian Ignimbrite (CI) about 34,000 yr bp, and the smaller Neapolitan Yellow Tuff (NYT) about 12,000 yr bp. Many other eruptions were originated from several eruptive centers, which gave rise to pyroclastic flows, tuff cones, scoria cones and fall deposits (Fig. 8). The last volcanic activity took place between 4,500 and 3,700 yr bp, mainly in the central area with numerous eruptions of Agnano, Academy, Solfatara, Astroni, Senga, Miseno, and ended with the eruption of Mt. Nuovo in 1538. This new phase of the eruption was preceded by a lifting phenomenon of the central part of the Phlegraean caldera, likely connected to the magma chamber refill.
At the moment, hydrothermal manifestations are just located in this central area, and appear to be related to the active volcanic areas.

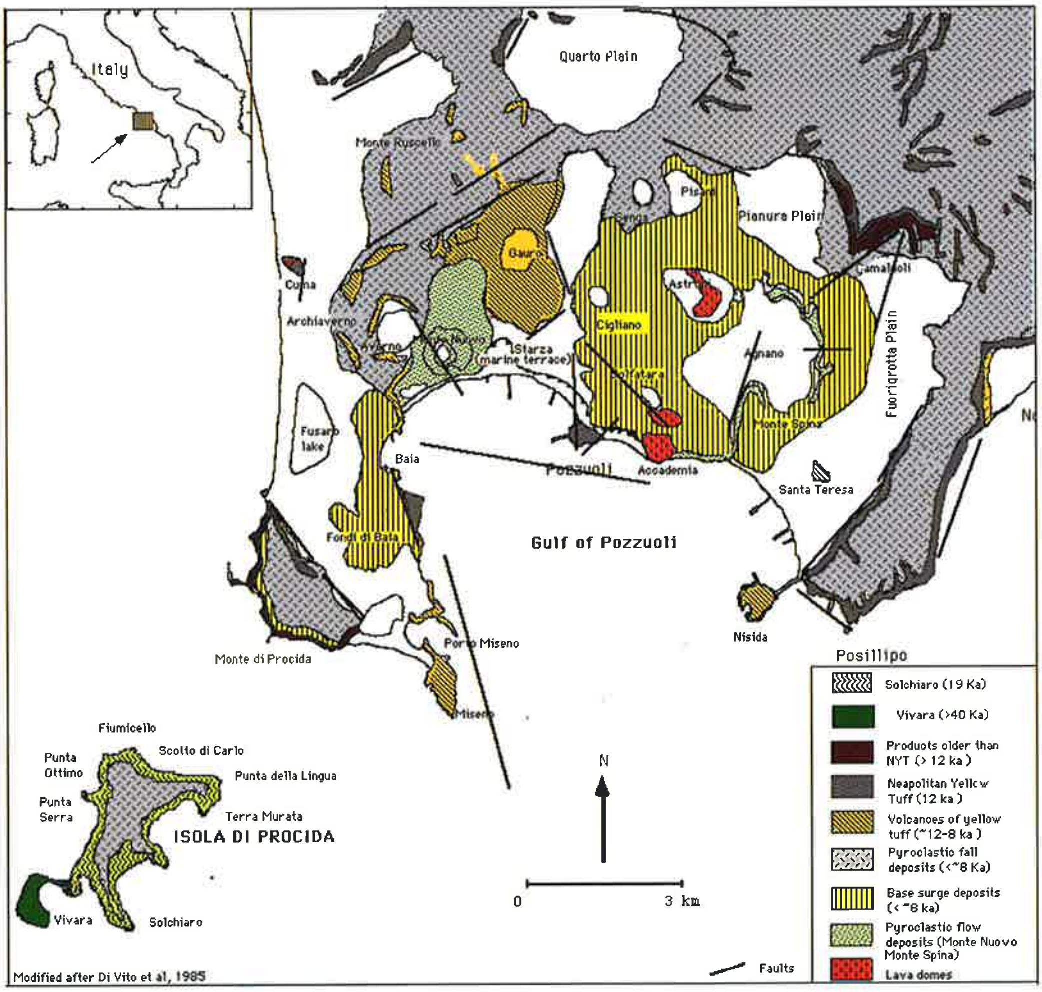

Figure 8. Geological map of Phlegraean Fields (from Di Vito et al. 1985).

SOLFATARA VOLCANO, THERMAL WATERS AND FUMAROLES

The Phlegraean caldera is affected by an intense hydrothermal circulation in both emerged and submerged zones. The most famous hydrothermal sites are Solfatara and Pisciarelli, located in the central area of the Phlegraean caldera, near the area of maximum lift of the caldera itself (Fig. 8). In

this area, there are many other hot springs and fumaroles, which are the expression of a geothermal system.
The wells and the previous studies revealed that the hydrothermal system consists of several overlapping geothermal reservoirs located between 3,000 and 1,000 m deep, the deepest of which contains saline fluids at high temperature (350-400 °C).
Temperatures of the thermal waters in the Phlegraean Fields vary between about 29 and 96 °C. The TDS vary from 2,500 mg/L (Terme of Lake Averno) to 22,000 mg/L (Stufe di Nerone). The waters of the Agnano and Averno areas are sodium bicarbonate type, with significant chloride content (from 300 to 3,024 mg/L). The waters of the Stufe di Nerone and Puteolane Spa are sodium chloride type.
The origin of these waters has been explained by mixing phenomena between meteoric water and diluted waters of marine origin. The content of major and minor elements is largely influenced by water-rock interactions.
The crater of Solfatara is a site of an intense hydrothermal activity which includes focused vents and areas of hot steaming ground. The fumaroles of Solfatara are formed by vapor (82%), carbon dioxide (1,500 tons per day are discharged by Solfatara), hydrogen sulfide, hydrogen, helium, etc. The fumaroles reach temperatures between 100 and 160 °C in Solfatara, and 100 °C in Pisciarelli. In both sites the fluids are extremely acidic and are characterized by significant magmatic component, linked to the degassing of deep magma.
The surveillance network of volcanic activity includes a continuous monitoring of gas emissions from soil and fumaroles. Figure 9 shows the temperature rise recorded in the Pisciarelli fumaroles since 2005 and phenomena caused by the increased issuance. Figure 10 shows the variation in the chemical composition of the Solfatara fumaroles: since 2000, the fumaroles were progressively enriched in magmatic component.

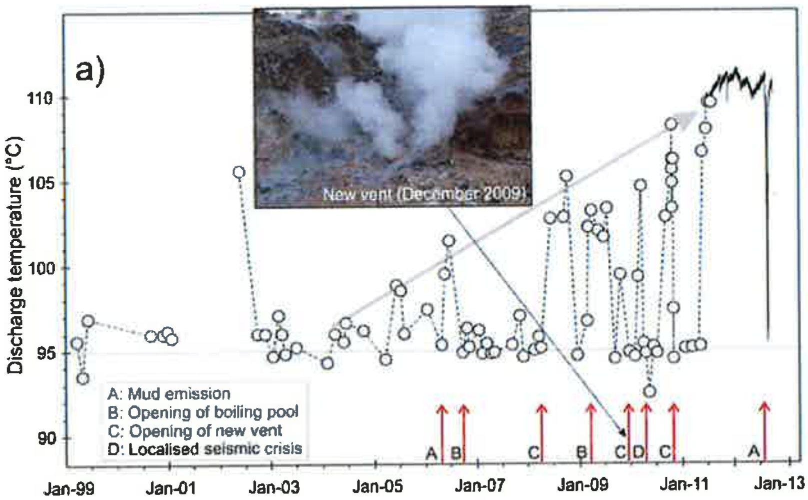

Figure 9. Temperature and hydrothermal phenomena recorded in Pisciarelli site from 1999 to 2013 (from INGV, Istituto Nazionale di Geofisica e Vulcanologia).

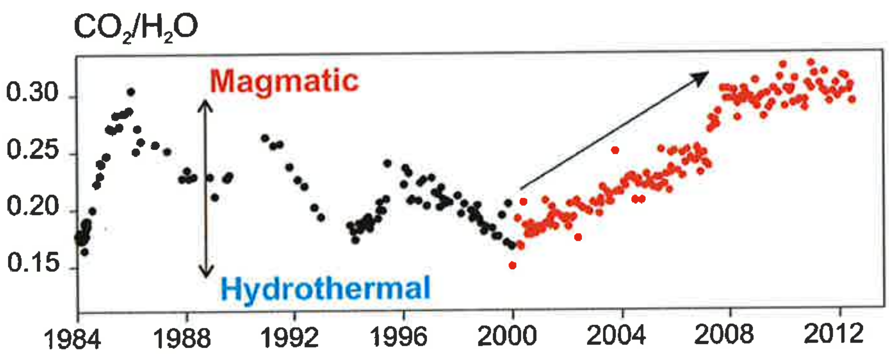

Figure 10. Change in the composition of the Solfatara fumaroles from 1984 to 2013 (from INGV, Istituto Nazionale di Geofisica e Vulcanologia).

SERAPEO AND BRADYSEISM

Since 1800, sea-level measurements made in the ruins of a roman market (Serapeo) have indicated a slow sinking of the area. These slow movements of the ground are called bradyseism (by the greek bradi=slow and seism=movement).

The Serapeo (Fig. 11), built near the sea-shore between the end of the I and the beginning of the II century AD, was restored at the beginning of the III century AD, because sea water invaded its floor. Then the ground was subsiding until the X century AD, when it began to uplift. This uplift lasted until the Monte Nuovo eruption (1538); in the last few days before the eruption an uplift of 5 to 8 m took place in the area. After the eruption the ground subsided until 1969.

Figure 11. The remains of Serapeo have been very useful for the reconstruction of bradyseism trend thanks to the holes produced by lithodomes on the columns.

Ground movement measurements made at the beginning of this century showed that the maximum deformation occurred in the town of Pozzuoli, and regularly decreased eastward and westward along the coast. In the periods 1970-1972 and 1982-1984, two important episodes of inflation were registered in the Pozzuoli area. During this periods, there was an intense seismic activity. In particular, the latest crisis has been accompanied by more than 10,000 earthquakes. Hypocenters were located between a few hundred meters until 5 km depth. The maximum observed magnitude was 4.0.

In the periods of rapid deformation of the soil, an increase in hydrothermal activity in the area of Solfatara was also observed.

Ground deformation is also included in the monitoring network of the volcanic activity. A summary of the history of ground deformation at Phlegraean Fields is represented in Figure 12.

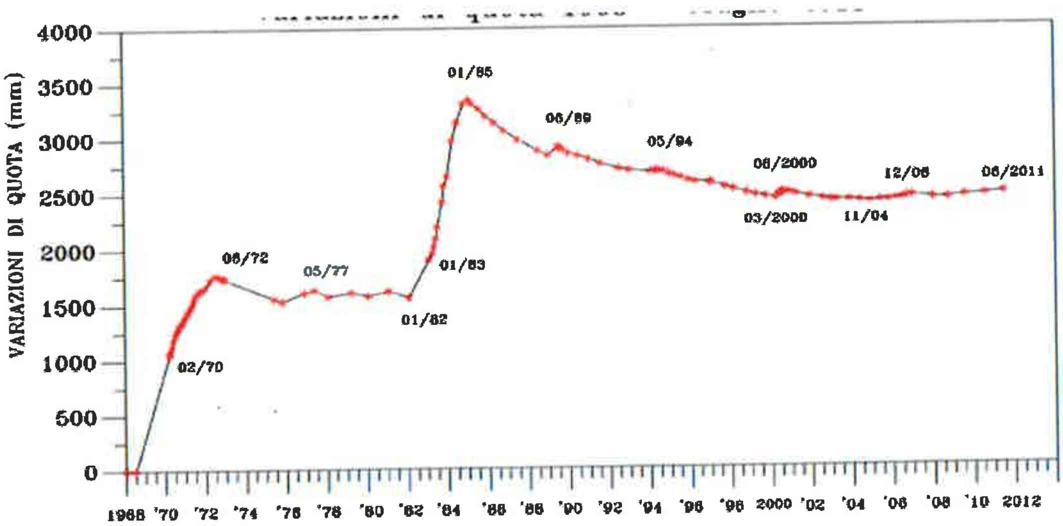

Figure 12. Variation of ground level (mm) from 1968 to 2011 in the centre of Pozzuoli (from INGV, Istituto Nazionale di Geofisica e Vulcanologia).

2nd Day - The Isle of Ischia

The volcanic activity of the island began 150,000 yr bp with explosive and effusive eruptions (scoria cones, tuff cones and lava domes). Around 60,000 yr bp, volcanic activity continued with Plinian and sub-Plinian eruptions, and then with a large ignimbrite eruption, i.e. Green Tuff of Mt. Epomeo (Fig. 13). These eruptions led to the total filling of a caldera structure, with large thickness of ignimbrite deposits that have assumed the typical green color due to circulation of hydrothermal fluids. After 56,000 yr bp, normal faults gave rise the progressive resurgence of central part of the island; subsequent erosion of ignimbrite units took place together with the formation of marine deposits. Around 30,000 yr bp, volcanic activity was concentrated in the peripheral parts of the central block and in the marine areas, with formation of tuff cones. From 30,000 to 18,000 yr bp, the volcanic activity mainly occurred in the SW (lava domes, welded scoria deposits, hydromagmatic tuffs and fall pumice deposits) and in SE sectors of the island (lava flows and fall pumice deposits). From 16,000 yr bp, the volcanic activity interested the peripheral areas of Mt. Epomeo with formation of domes and tuff cones. In this period, landslides related to the resurgence of Mt. Epomeo occurred. From 5,000 yr bp, explosive and effusive eruptions followed in the N and NE sectors, ending with the Arso eruptions in 1302 (Fig. 13).

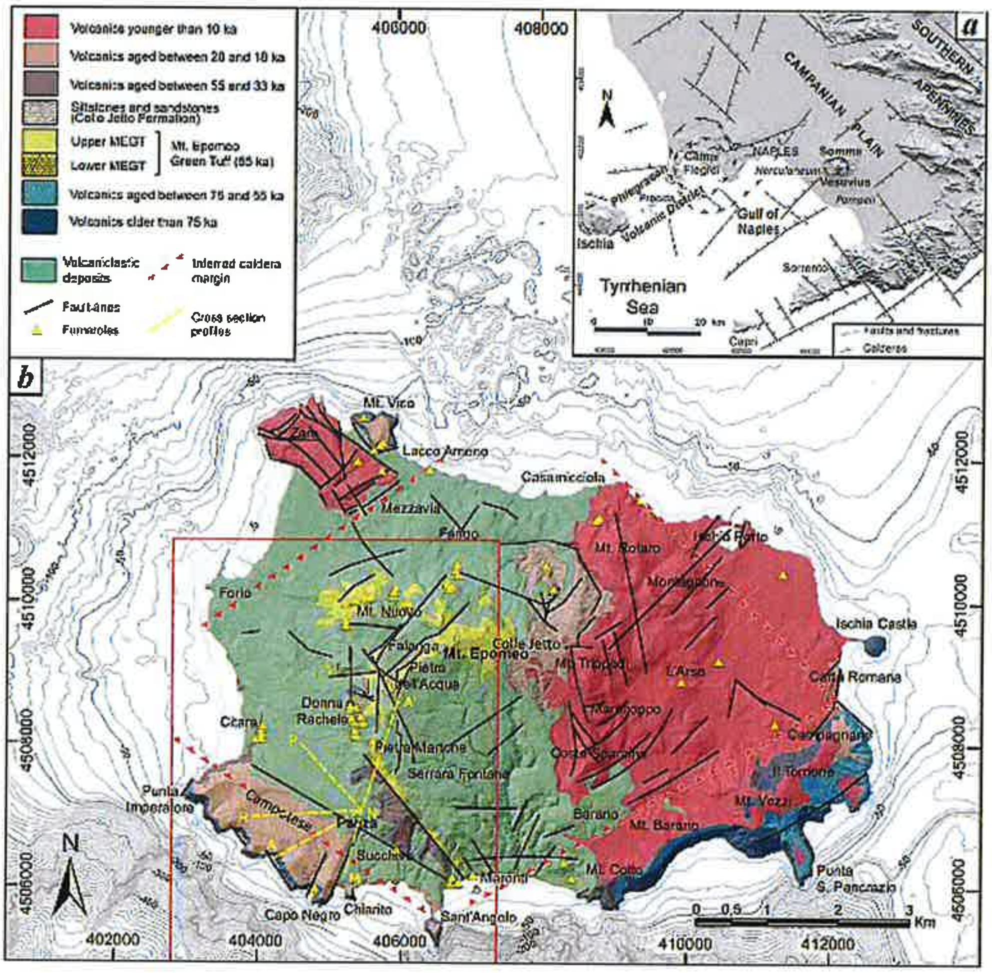

Figure 13. Schematic geological map of Ischia (from Di Napoli et al. 2011).

The geothermal system of the island has been fed by magma with temperatures around and above 1,000 °C stored in a very shallow chamber, partly cooled and crystallized. The heat flow of the magmatic masses influences the active circulation of meteoric waters, waters of marine origin and deep fluids (gases). The island is affected by a very high heat flow between 200 and 400 mW/m^2.
Two types of hydrothermal events characterize the island. The first type includes fumaroles fields and localized emissions with high temperatures (100-115 °C), related to the tectonic structures that border

of Mt. Epomeo. The second type includes hot springs (20-90 °C) distributed in coastal areas, in the hilly areas around of Mt. Epomeo and in thė marine areas (Fig. 14).
The first type of event is represented mainly by extensive fields of fumaroles and steaming grounds, the field of Rione Bocca is the most active and extensive. Vapor dominant characterizes the fumaroles of this area: the water vapor reaches the 99.8%, other gases (mainly CO_2 and secondly H_2S, H_2, N_2, NH_3, CH_4, Ar, He, and CO) are present. Isotope geochemistry studies have shown that these fumaroles are fed mainly from meteoric waters, with a contribution of magmatic fluids (for He, Ar, N_2 and CO_2).

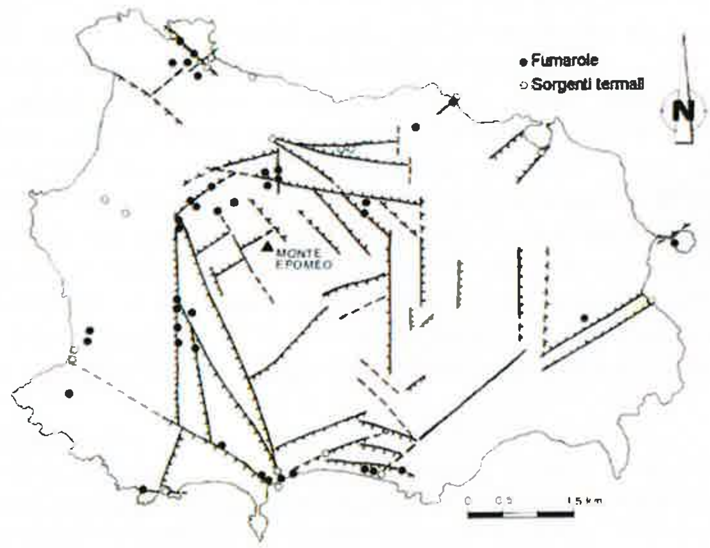

Figure 14. Location of the main fumaroles, thermal springs and faults (from Vezzoli 1988).

Groundwater of the island, based on the content of major chemical constituents, can be classified in six types of water (Fig. 15).

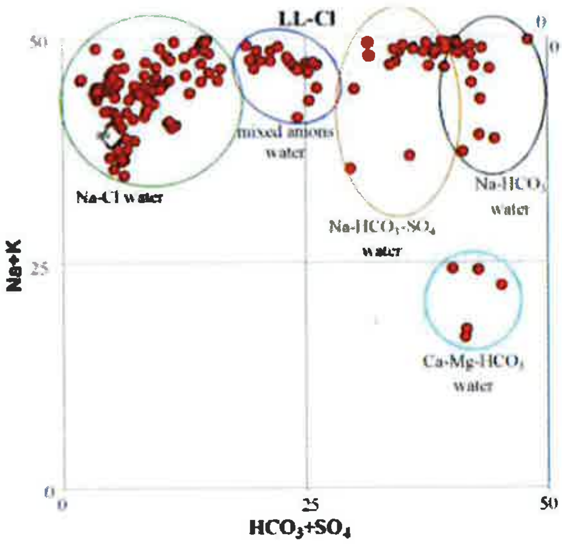

Figure 15. Langelier-Ludwig plot (from Sbrana et al. 2009; 2010).

Alkaline and earthy-alkaline bicarbonate waters characterize cold springs of the island. TDS and temperature are 600-800 mg/L and 19-23 °C, respectively.
Sodium bicarbonate waters characterize water wells mainly located in the Citara-Cuotto zones close to the slopes of Mt. Epomeo, near areas with fumarole emissions. Temperatures can reach values up to 90 °C, the TDS varies between 1,600 and 4,100 mg/L.
Sodium bicarbonate-sulfate waters are mainly present in the area of La Rita-Bagni, on the northern slope of Mt. Epomeo. The temperature varies between 17 and 83 °C. The average TDS is of 4,200

mg/L and the average content in bicarbonate is rather high (1,600 mg/ L). These waters derive from the infiltration of meteoric water modified by the addition of deep gases or vapors (mainly CO_2 and H_2S).

Sodium chloride-sulfate waters characterize two areas: the area of Succhivo, in the southern coastal area, and the area of Monterone, on the slopes of Monte Nuovo. For the Succhivo area, the temperature varies between 64 and 82 °C and TDS between 5,600 and 6,700 mg/L. The spring waters of Monterone have TDS between 3,500 and 4,900 mg/L, and temperature ranges between 33 and 41 °C.

Sodium chloride waters characterize the coastal wells (especially those locate in the village of Ischia Porto). The TDS varies from 1,500 to 46,000 mg/L, and temperatures are between 24 and 99 °C. These waters are influenced by marine intrusion and fluids of deep origin.

Waters with mixed anions characterize springs and wells where mixing phenomena between bicarbonate meteoric and chloride waters occurred. The temperatures are very variable (between 24 and 75 °C), as well as the TDS (between 1,400 and 8,200 mg/L).

Based on this geochemical classification, the variety of chemical waters is explained as below. The deep geothermal fluids with low salinity ascent to the surface through fractures and faults, giving rise to complex phenomena of water-rock interaction and/or dilution of groundwater in different composition. In the inner part of the island, bicarbonate (sulfate) waters of meteoric origin interact with CO_2 and H_2S, which derive from the deep degassing of the geothermal system at high temperature. Along the coast, the "top" of the geothermal reservoir is locally intruded by sea water.

A BRIEF HISTORY OF ISCHIA SPA

The thermal springs of Ischia were discovered by the Greek settlers in the VIII century BC. The Romans were the first to use these springs as swimming pools. They viewed them as a place for the relax of the body and mind, in addition to simple hygienic purposes. The volcano-tectonic events canceled the traces of this primitive use of the thermal waters of Ischia. Between the III and IV century, the spas were abandoned for a few centuries, because of the earthquakes, the volcanic activity and the crisis of the Roman Empire.

In the Middle Ages, spas resumed slowly their activities, rising again during the Renaissance with the rediscovery of the medical culture. In 1300, some spas of the island (Succellaro, Citara, del Lago, Vico) began to be mentioned in more specific sense. In the XVI century, a period of studies and new discoveries of hydrothermal resources began.

In 1588, the doctor Giulio Iasolino published one of the most comprehensive treaty of medical hydrology, describing 59 *praesidia naturalia*, 35 hot springs, 19 saunas and 5 hot sand sites. Physical and chemical properties, methods of use and medicinal virtues of each water were described.

At the beginning of the XVII century, the first hydrotherapy social center was born, which gave impetus to the development of the area of Bagni, where many spas were built.

In 1783, the doctor and professor at the Royal University of Naples, Nicola Andria, wrote a *Treaty on mineral water* which is the first book about medical hydrology.

The spas of the island experienced their heyday in the XIX century, with numerous hotels frequented by a large number of customers, many artists, writers and foreign travelers of the Grand Tour (de Lamartine, Renan, Ibsen, Berkeley, Gay Lussac, Stendhal, etc.).

The violent earthquake of 1883 destroyed this flourishing activities and erased all the urbanized areas of the island. In the 50s, the spa tradition of the island begins its recovery. Through an international conference on hydrology and therapy, spa resources were exploited and internationally re-launched, historical spas were rebuilt.

From the 60s, old spa facilities were renewed and new hotels were built in order to satisfy an increasing touristic demand. From the 70s, new wells tapping the thermal waters have been added to the waters of the ancient springs. New hotels with spas, swimming pools and spa parks were built. Currently, there are 180 spas and 130 swimming pools. The thermal waters of the island have broad and multiple therapeutic applications, because of the peculiar healing actions for the skin, mucous membranes and other apparatuses.

NITRODI SPRING

The Nitrodi Spring is located on the southern slope of Mt. Epomeo (Fig. 16), at an altitude of about 200 m asl. Pyroclastic formations (45,000-38,000 yr bp) outcrop in the area, including fall, surge and flow pyroclastic deposits, covered by debris and landslide deposits.

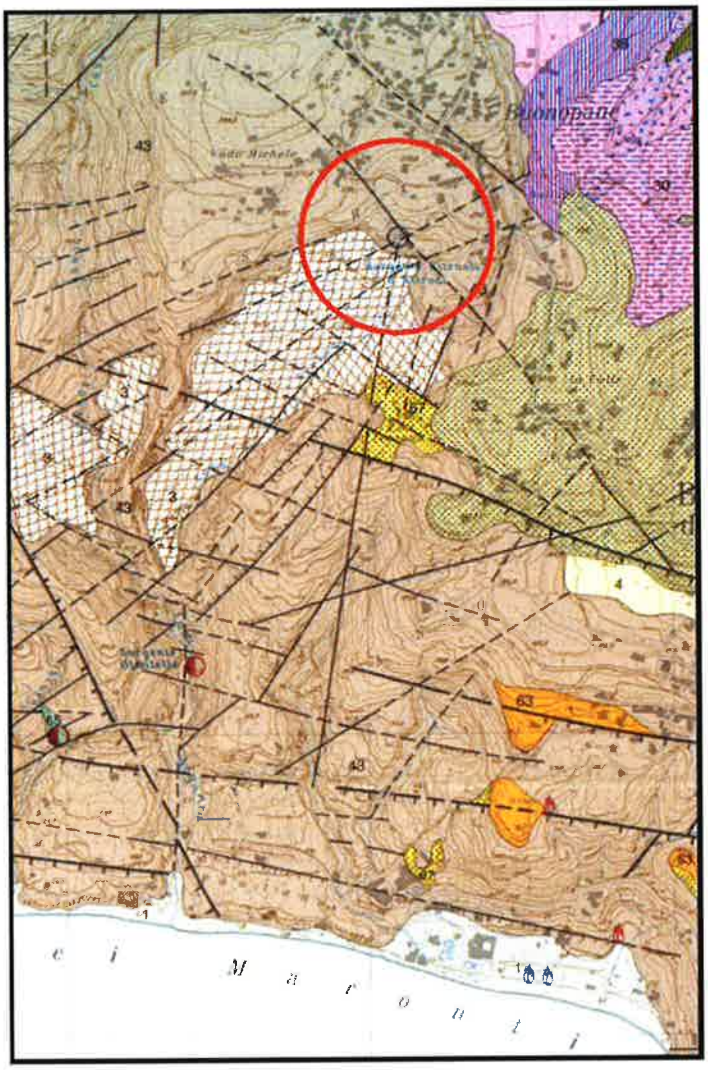

Figure 16. Location of Nitrodi spring.

The spring has a flow rate of about 3.5 L/s. The water is classified as alkaline bicarbonate type; TDS and temperature are 1,100 mg/L and 28 °C, respectively.

Based on the water characteristics, the elevation and the local stratigraphy, the spring can be related to a perched aquifer. Other examples of this type of spring are present in the northern slope of Mt. Epomeo (Fig. 17). They are representative of relatively short circuits in the debris deposits and the most superficial layers of pyroclastic deposits. These springs are mainly fed by meteoric water and little affected by the heat flow of the island, except when they are located near faults and fractures.

The Nitrodi Spring was discovered by the Romans. In 1759, a series of votive slabs, depicting Apollo and the Nymphs Nitrodi in the act of pouring the water, were found at the spring. The waters of the spring can be used for healing purposes, such as the skin wealth and the oral cavity inflammation treatment.

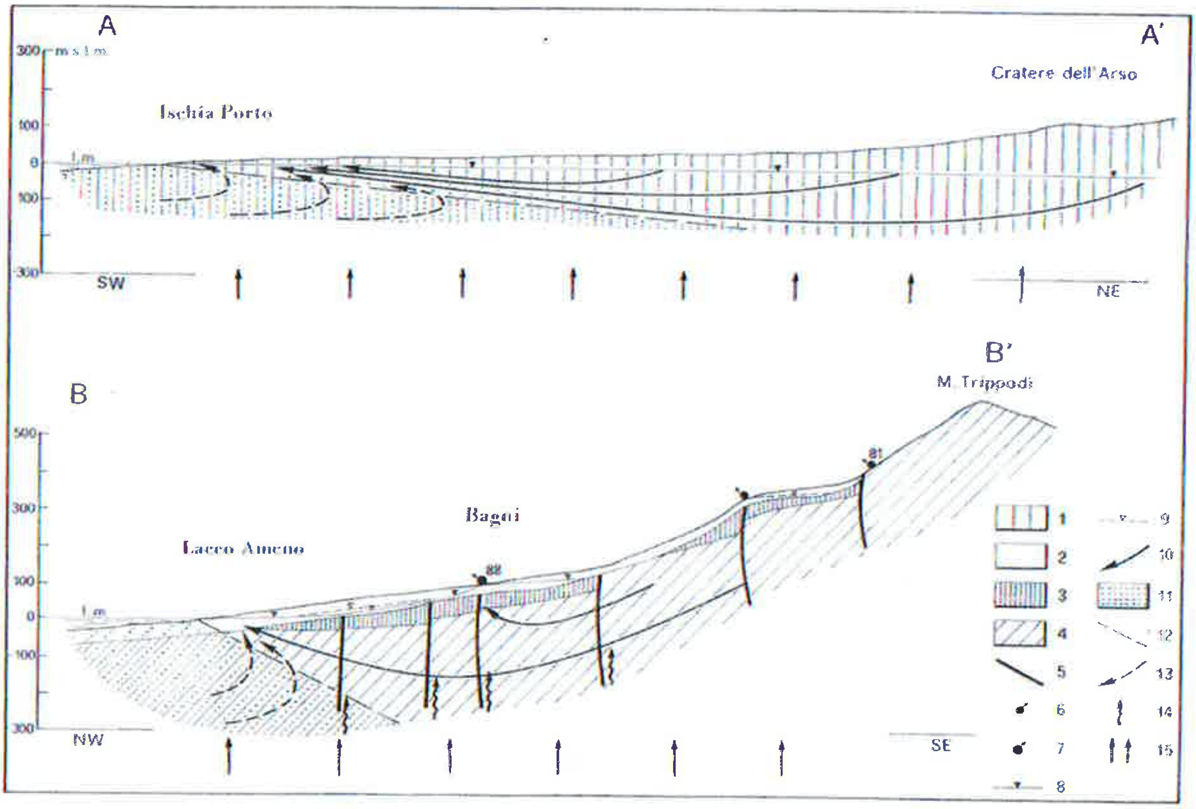

Figure 17. Hydrogeological cross-sections through the graben of Ischia (A-A') and northern slope of Mt. Epomeo (B-B'): 1 Aquifer (pyroclastic deposits and lavas), 2 Aquifer (pyroclastic and debris deposits), 3 Aquitard (marine and pyroclastic deposits), 4 Aquifer (tuffs and ignimbrites), 5 Main faults and fractures, 6 Spring, 7 Thermal spring, 8 Groundwater level of the basal aquifer, 9 Groundwater level of the perched aquifers, 10 Flow direction of the basal aquifer, 11 Sea water intrusion, 12 Sea water interface, 13 Rising of sea water, 14 Rising of deep fluids, 15 Heat flow (from Celico et al. 1999).

MARONTI BEACH

The coastal area between the beach of Maronti and the promontory of St. Angelo is one of the hottest of the island. In this area, there are important fields of geysers (Fig. 18), steaming grounds and wells of thermal waters. Groundwater is sodium chloride and sodium sulfate-chloride type; the temperature is 60 to 80 °C, the TDS varies from 16,000 to 42,000 mg/L. This is due to phenomena of marine intrusion and rising of deep fluids.

Figure 18. Geyser vent during the drilling of a well in August 1939.

The area is one of those interested by geothermal research in the past. The first drillings on the island were carried out in the period 1939-1943 and then later in the period 1951-1954 by the SAFEN company. 90 wells were drilled, 9 of which had a depth greater than 100 m (Fig. 19). The deepest well was built in the western sector of the island (Forio) and reached 1,151 m depth by detecting a maximum temperature of 225 °C.
In the south of the island, between St. Angelo and Maronti, different wells were also drilled (Fig. 19).

Figure 19. Location of wells drilled by SAFEN from 1939 to 1950, red circles indicate deep wells (>500 m) (from Carlino et al. 2012).

In addition to the detection of the stratigraphy and the log of temperature, some wells were used for pumping tests. Figure 20 shows that the temperature reaches 100 °C in a few tens of meters deep.
Data from these perforations highlighted that much of the potential production of geothermal energy in Ischia is related to vapor-dominated system. Attempts to use the geothermal resource of the island were begun in 1939. The project was then abandoned, the reasons being the low technology level at the time, and the imminent war danger. On the beach of Cetara, in the eastern sector of the island, a well with temperature of 176 °C produced up to 70 m^3/h of water and 100 t/h of steam. Currently, a new research has been undertaken for the use of the geothermal resource of the island.

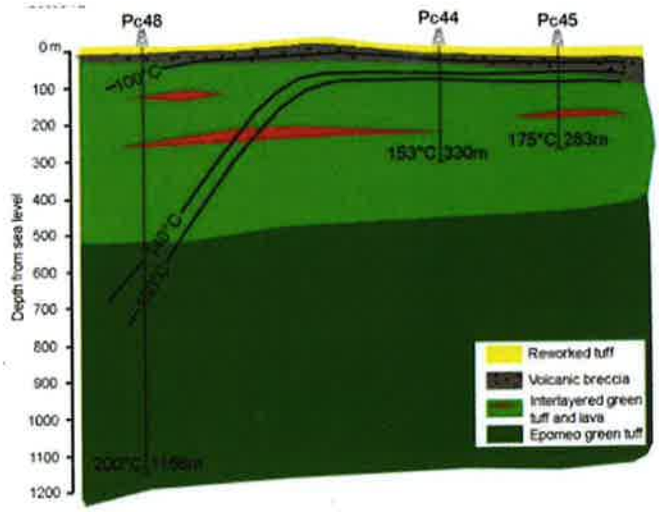

Figure 20. Cross-section along the coastline of Maronti-St. Angelo showing the temperature distribution in the subsoil (from Carlino et al. 2012).

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