Third Edition

RISK MANAGEMENT

Knowledge, Forecasting, Prevention, Protection, Planning, Preparedness

20 - 27 July 2025

GROUNDWATER ECOSYSTEM SERVICES: CHALLENGES AND FUTURE OPPORTUNITIES

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ORVIETO

25 July 2025

Water resources and sustainable development

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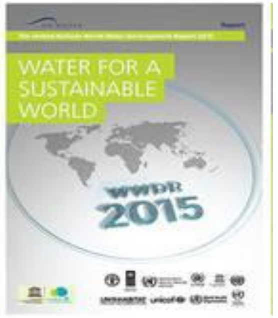
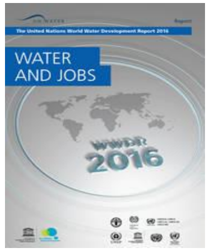
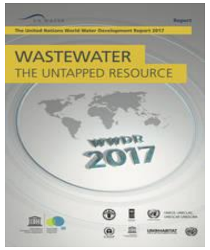
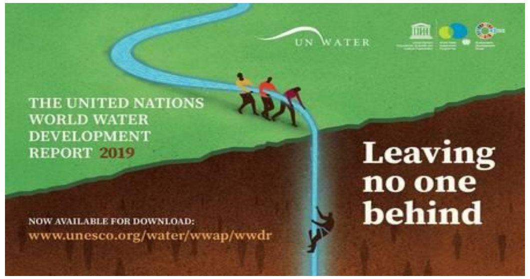
CONSIGLIO NAZIONALE DEI GEOLOGI

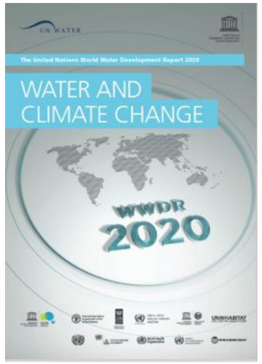
Water resources and sustainable development

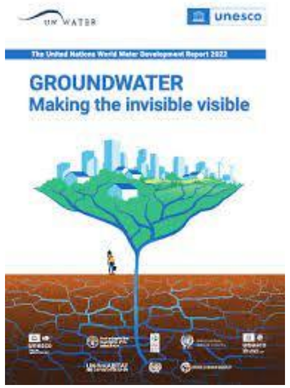






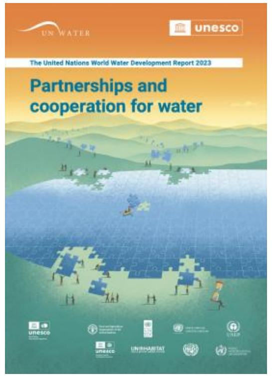


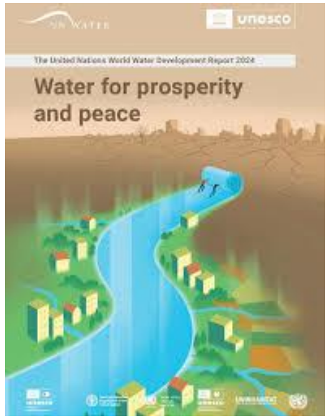




UNESCO WWAP – WORLD WATER ASSESSMENT PROGRAMME

- ✓ Monitor, assess and report on the world's freshwater resources and ecosystems, water use and management, and identify critical issues and problems;
- ✓ Help countries develop their own assessment capacity;
- ✓ Raise awareness on current and imminent/future water related challenges to influence the global water agenda;
- ✓ Learn and respond to the needs of decision-makers and water resource managers;
- ✓ Promote gender equality;
- ✓ Measure progress towards achieving sustainable use of water resources through robust indicators; and
- ✓ Support anticipatory decision-making on the global water system including the identification of alternative futures.





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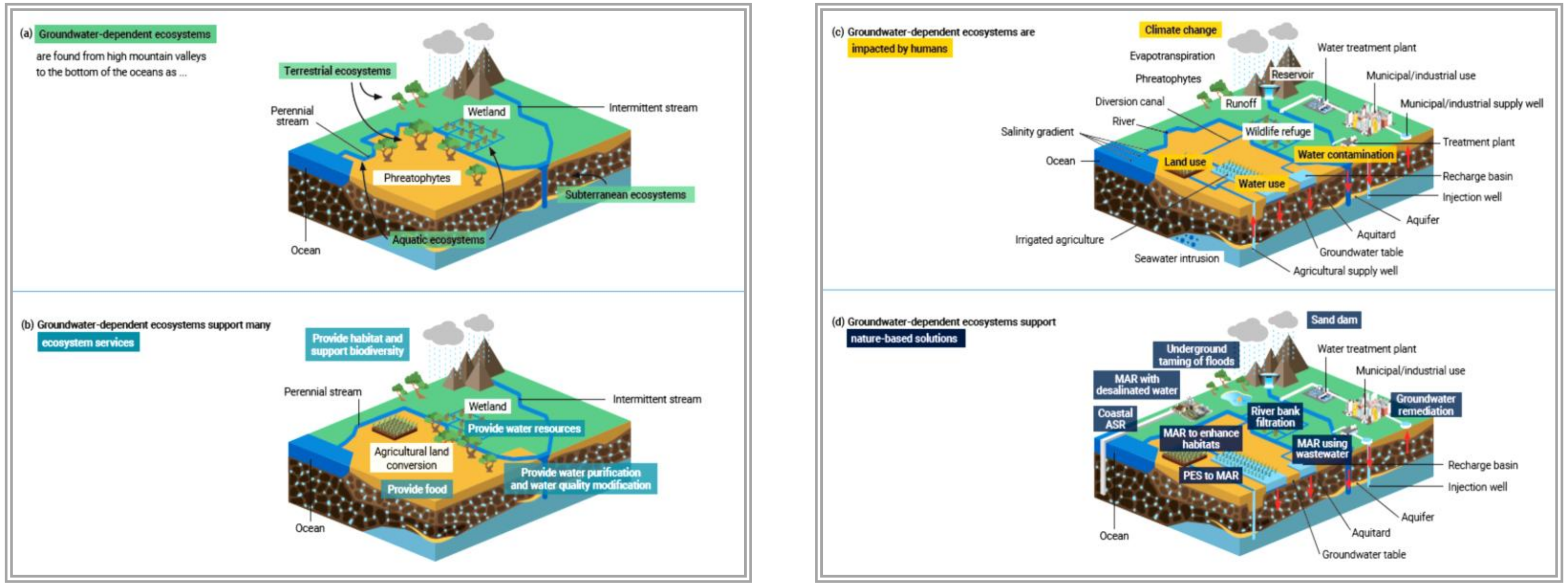
Water resources and ecosystem services

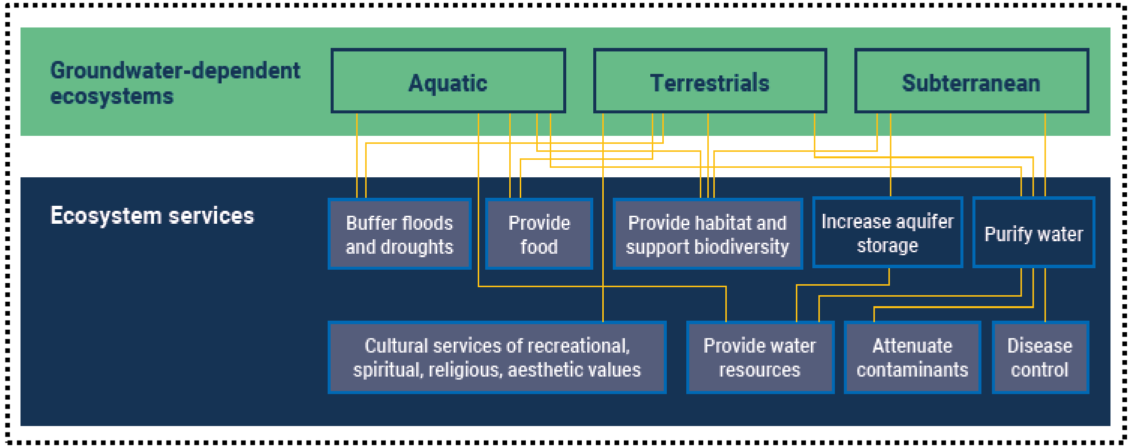
Groundwater

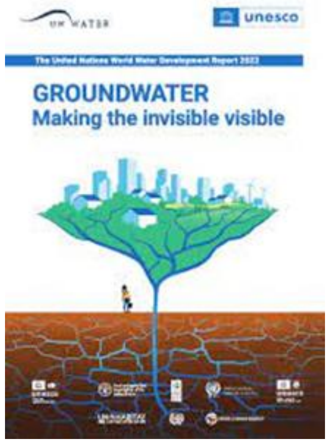
Interactions between groundwater, ecosystems, human activity and nature-based solutions



Sources: (a), (b) and (c) based on Maven's Notebook (2015); (d) based on Villholth and Ross (n.d.)

Connecting groundwater-dependent ecosystem types (GDEs) with the ecosystem services they provide





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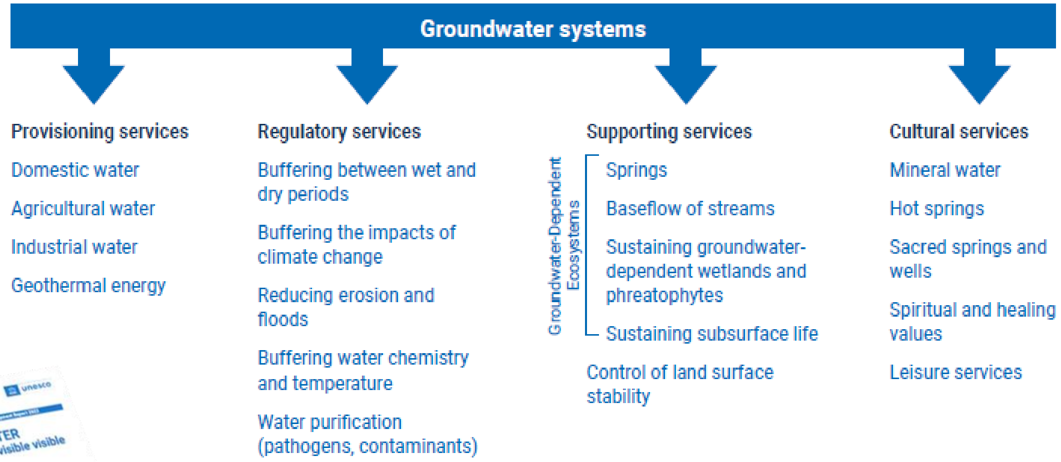
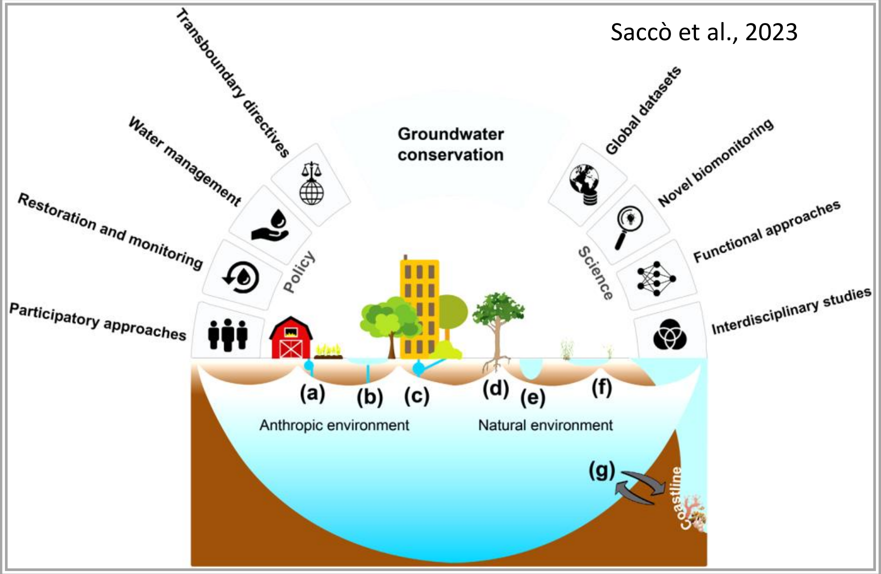
Water resources and ecosystem services

Groundwater



Ecosystem services are defined as the numerous and wide-ranging benefits to humans afforded by the natural environment (IPBES, 2019). GDEs support critical ecosystem services. Each type of GDE supports a number of ecosystem services across the categories of supporting, provisioning, regulating and cultural services



Examples of groundwater ecosystem services within anthropic (a, b, c) and natural (d, e, f, g) frameworks and recommended guidelines for groundwater conservation in terms of scientific advancements (top right) and policy developments (top left).

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Water resources and ecosystem services

Groundwater

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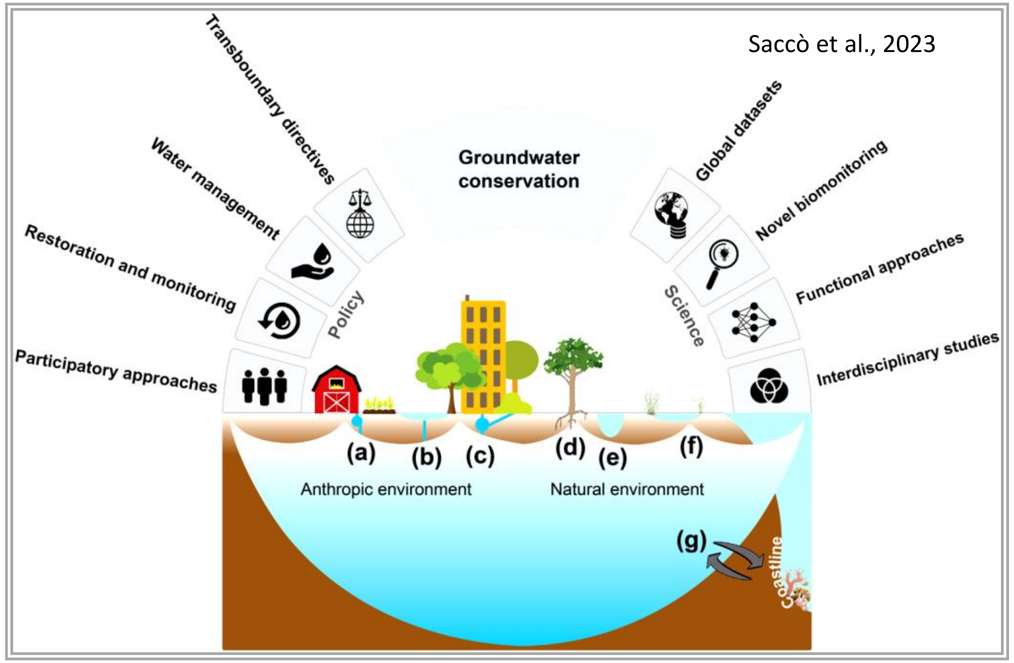

Examples of groundwater ecosystem services within anthropic (a, b, c) and natural (d, e, f, g) frameworks and recommended guidelines for groundwater conservation in terms of scientific advancements (top right) and policy developments (top left).

Tavolo 3
Governo delle acque: futuro e sostenibilità

Antonio Alba
Alberto Alfinito
Giovanni P. Beretta
Nicola De Zorzi
Silvia Fabbrocino
Mauro Grassi
Giorgio Guarini
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Marco Petitta
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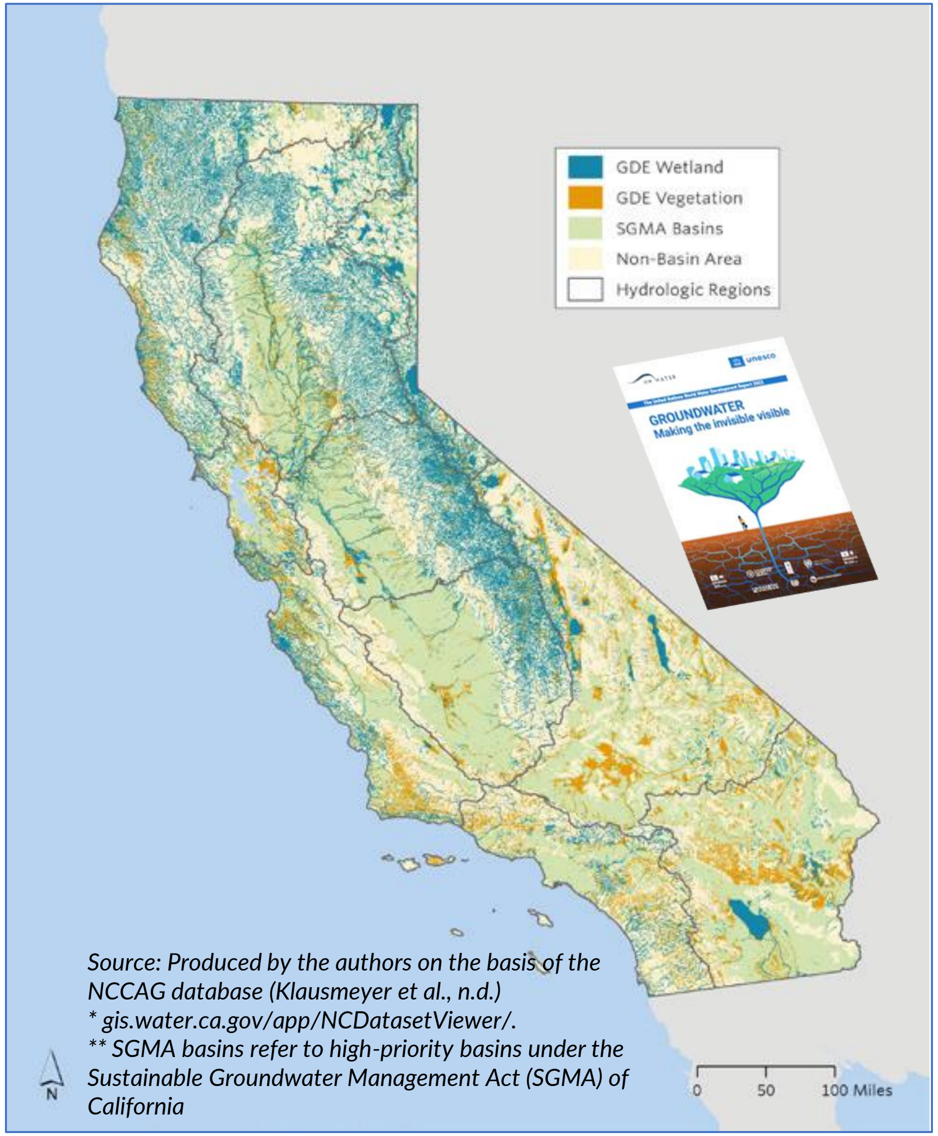
Water resources and ecosystem services

Groundwater mapping and policy



Source: Produced by the authors on the basis of the NCCAG database (Klausmeyer et al., n.d.)
** gis.water.ca.gov/app/NCDatasetViewer/.*
*** SGMA basins refer to high-priority basins under the Sustainable Groundwater Management Act (SGMA) of California*

Mapping groundwater-dependent ecosystems in California

Policy	Overall aim	The role of GDEs and how they are included in the policy
Ramsar convention	Protection of habitats	This agreement provided the first framework for protection of wetlands on a voluntary basis.
Birds directive	Protection or birds	Protect breeding and resting areas of which some are GDE.
Habitats directive	Protection of habitats and biodiversity	Protect valuable habitats of which many are GDE such as wetlands and springs. Natura 2000 sites form a EU-wide network of protected areas.
Water Framework Directive	Sustainable use of water resources and to achieve good surface water quality	WFD Guidance document 12 state: (I) Protect, enhance and restore wetlands identified as water bodies, where this is necessary to support the achievement of good ecological status or potential. (II) Prevent more than very minor anthropogenic disturbance to the hydromorphological condition of surface water bodies at high ecological status including the structure and condition of riparian, lakeshore or inter-tidal zone and hence the condition of any wetlands encompassed by these zones. (III) Establish measures to control and mitigate modifications to the structure and condition of riparian zones within wetlands. (IV) Wetlands could play a relevant role in facilitating the achievement of other WFD requirements concerning protected areas that do not target wetlands directly.
Directive on Groundwater Protection	Achieve good groundwater status, prevent deterioration (quantitative and chemical), prevent or limit the input of pollutants, implement measures to reverse any significant and sustained upward trend in groundwater bodies	GDEs have a central role in since the update of the directive in 2006. Groundwater bodies are classified as poor if GDEs are damaged due to pollution from groundwater or less groundwater due to other groundwater uses. The directive requires to control and remedy anthropogenic alterations to groundwater quality and water levels to the extent needed to ensure that such alterations are not causing (I) significant damage to terrestrial ecosystems that directly depend on groundwater bodies and (II) significant diminution in the chemical or ecological quality of bodies of surface water associated with bodies of groundwater.
Flood Risk Management Directive	Reduce vulnerability to floods	This directive will be implemented in conjunction with the WFD through the coordination of flood risk management plans and RBMPs. Water retention measures are encouraged as an important buffer in the prevention of flooding. This will help to conserve wetlands (and other GDEs).
Climate change (EU white paper)	Reduce vulnerability to the impact of climate change	Actions mentioned include: (I) to address biodiversity loss and climate change in an integrated matter, and to (II) explore the potential for policies and measures to boost ecosystem storage capacity for water. Guidelines should be drafted by 2010 to deal with the impact of climate change on the management of Natura 2000 sites.

Klove et al., 2011

Relevant EU policies and their role in GDE management

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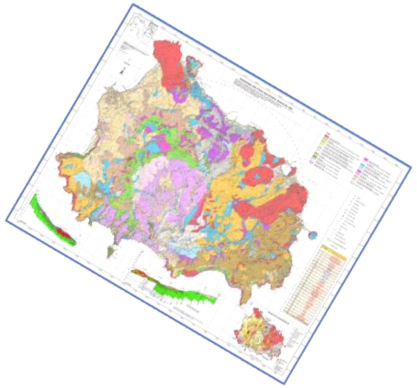
Groundwater and active volcanic areas

Ischia Island



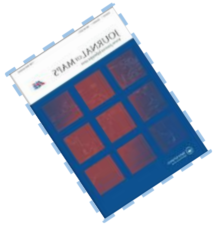
The map of Ischia, engraved by Mario Cartaro, is dated August 15, 1586.

DE RIMEDI NATVRALI
CHE SONO NELL'ISOLA DI
PITHECVSA; HOGGI
DETTA ISCHIA.
LIBRI DVE.
DI GIVLIO IASOLINO Filosofo, & Medico in Napoli.
Nelli quali si dimostrano molti rimedi naturali, dal detto Autore nuouamente ritrouati, oltre quelli, che lasciarono scritti gli Antichi.
Con molte esperienze, & historie, dal medesimo osseruate; come nel Sommario della seguente faccia si legge.
Con due tauole copiose.
All' Illustriss. & Eccellentiss. Sig. D. GERONIMA
Colonna, d' Aragona.
CON LICENZA, E PRIVILEGIO.

In Napoli Appresso Gioseppe Cacchij, M.D.LXXXVIII.

«Già sono quattordici anni ne' quali io di mia libera volontà, per comune utilità del mondo, così aiutandomi la divina bontà e clemenza, ogn'anno vado visitando questi bagni d'Ischia, vedendo diligentemente i luoghi et esaminandovi tutte le miniere et le cave, et finalmente, co'l maggior giuditio che posso, osservando i varii et stupendi effetti et utilità che operano ne corpi ammalati e ne gli sani»

Jasolino, De' Rimedi, cit., 164



The first hydrogeological map of Ischia Island

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Groundwater and active volcanic areas

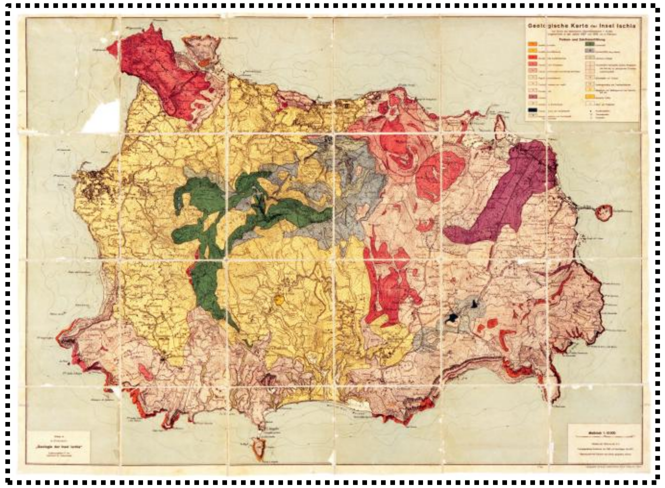
Ischia on the geological maps

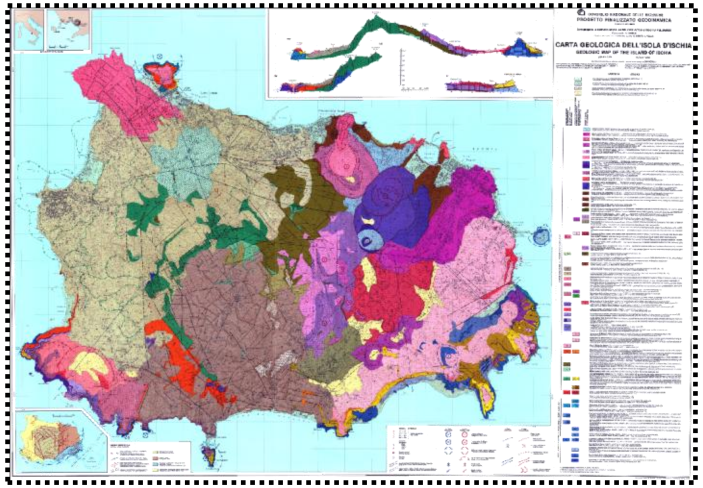
Rittmann, 1930

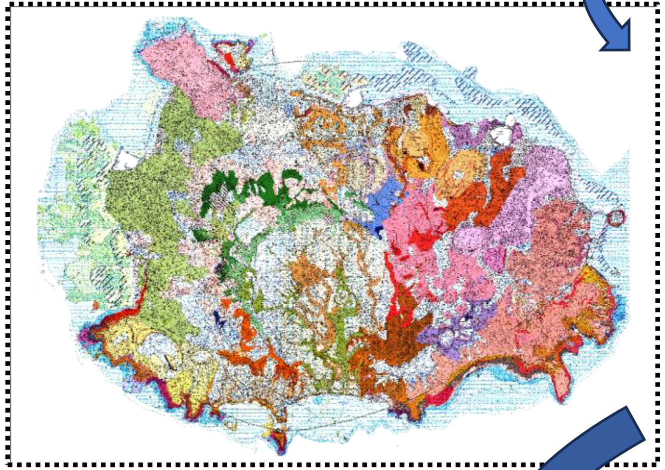
Vezzoli, 1988

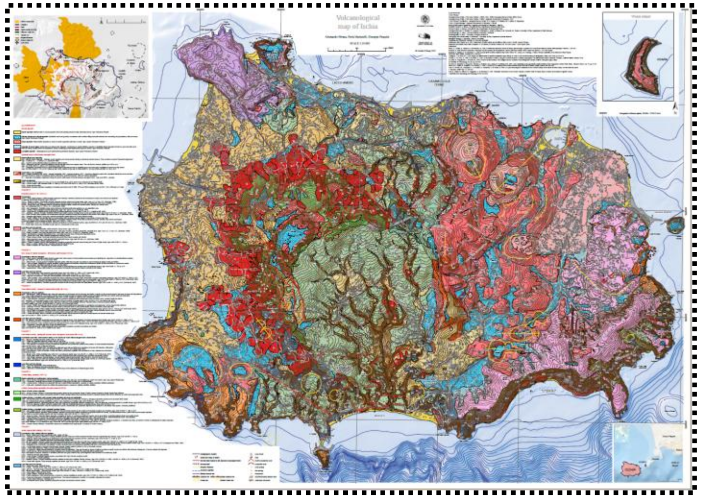
Sbrana & Toccaceli, 2011

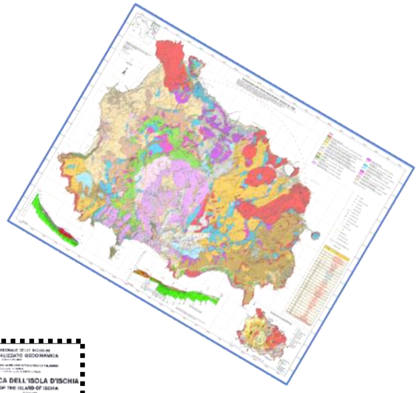
Sbrana et al., 2018

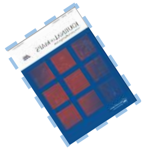












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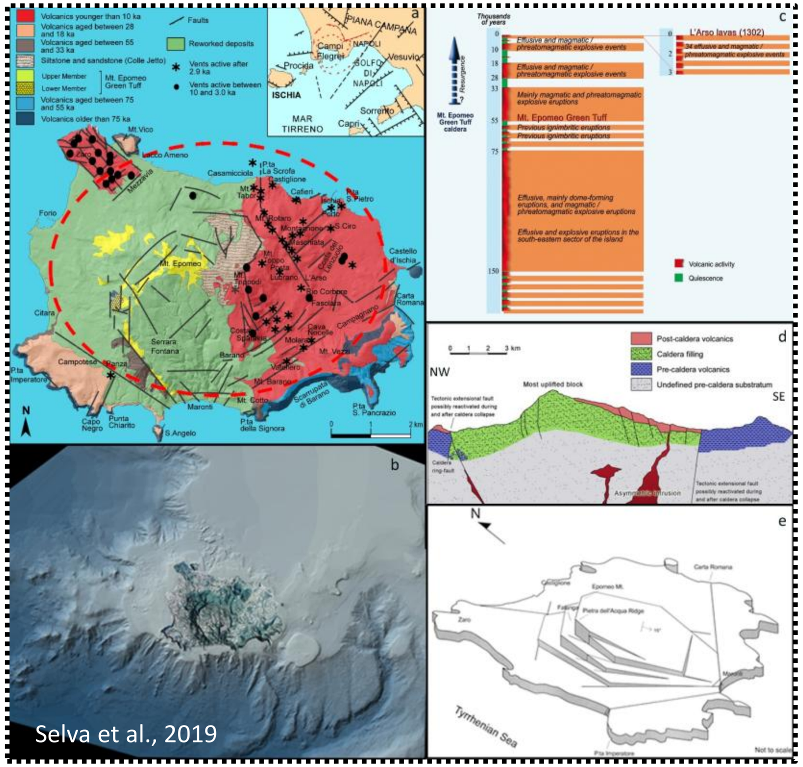
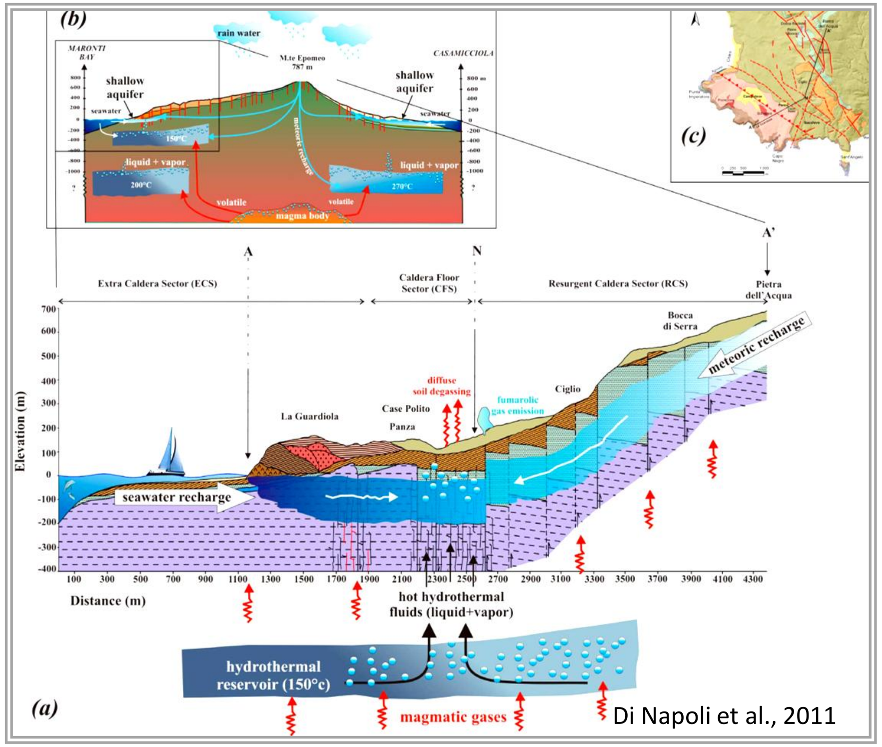
CONSIGLIO NAZIONALE DEI GEOLOGI

Groundwater and active volcanic areas

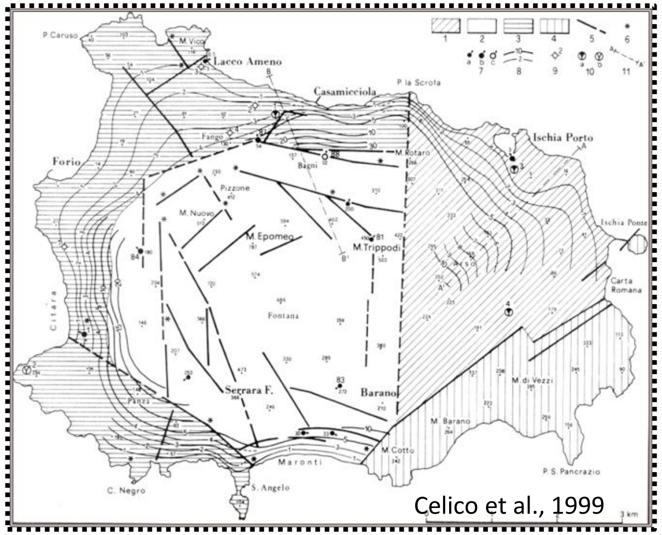
Groundwater flow and deep hydrothermal system



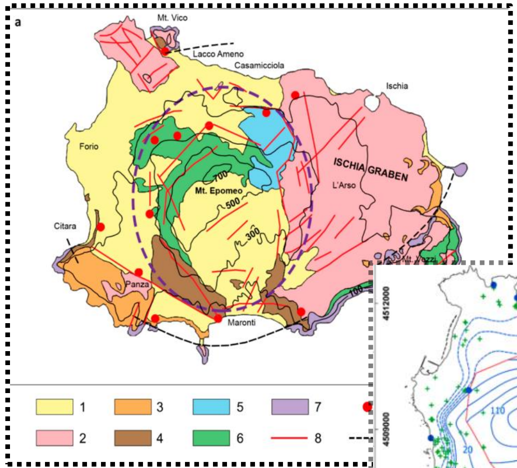
Selva et al., 2019

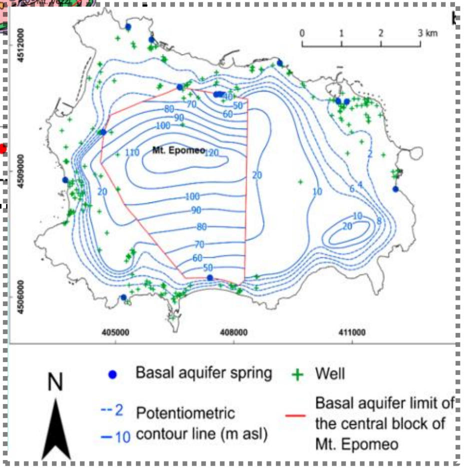


Di Napoli et al., 2011

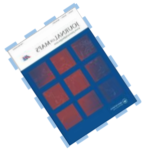


Celico et al., 1999





Piscopo et al., 2020



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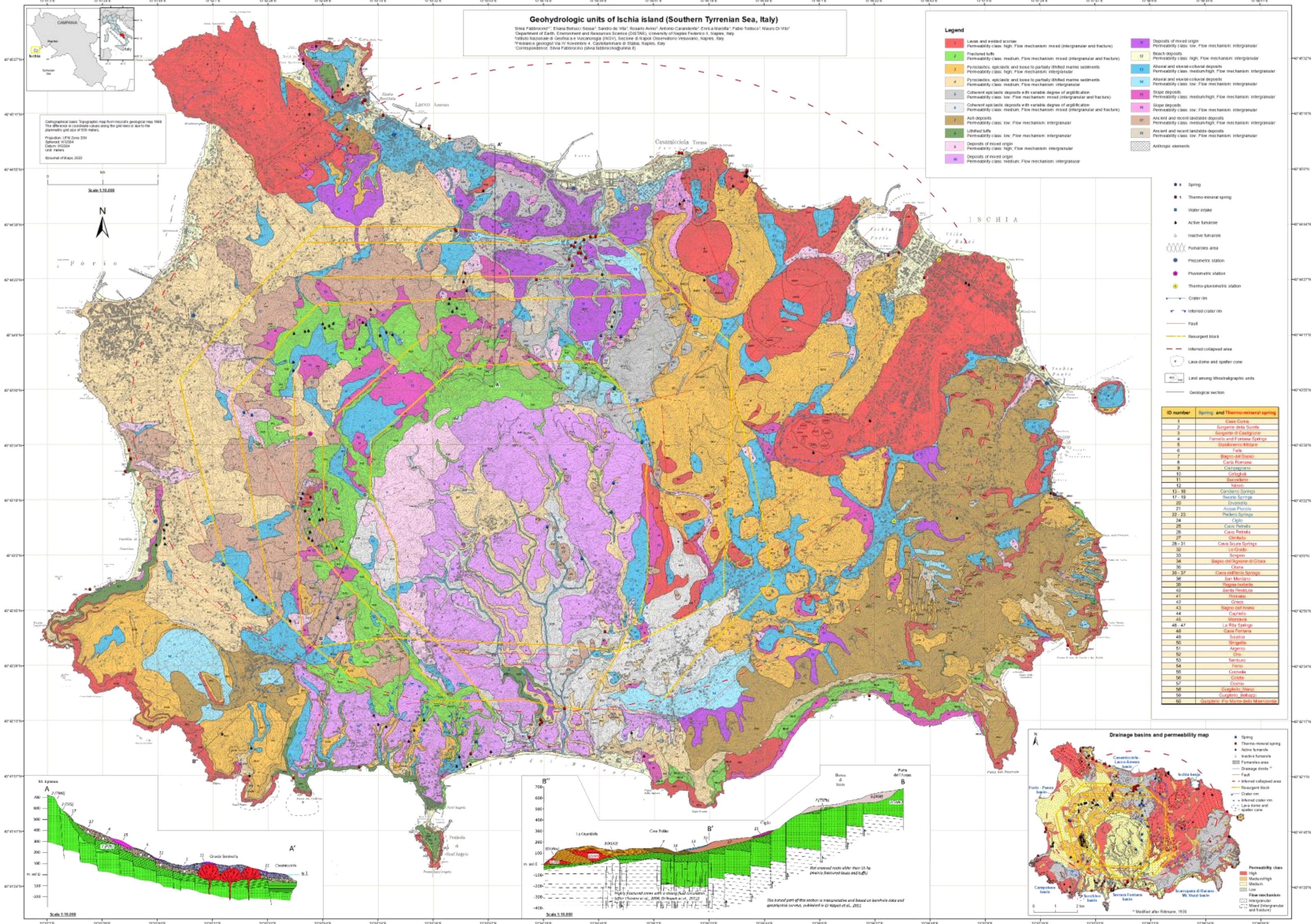
Groundwater and active volcanic area

Geohydrologic units of Ischia Island



Fabbrocino et al., 2024

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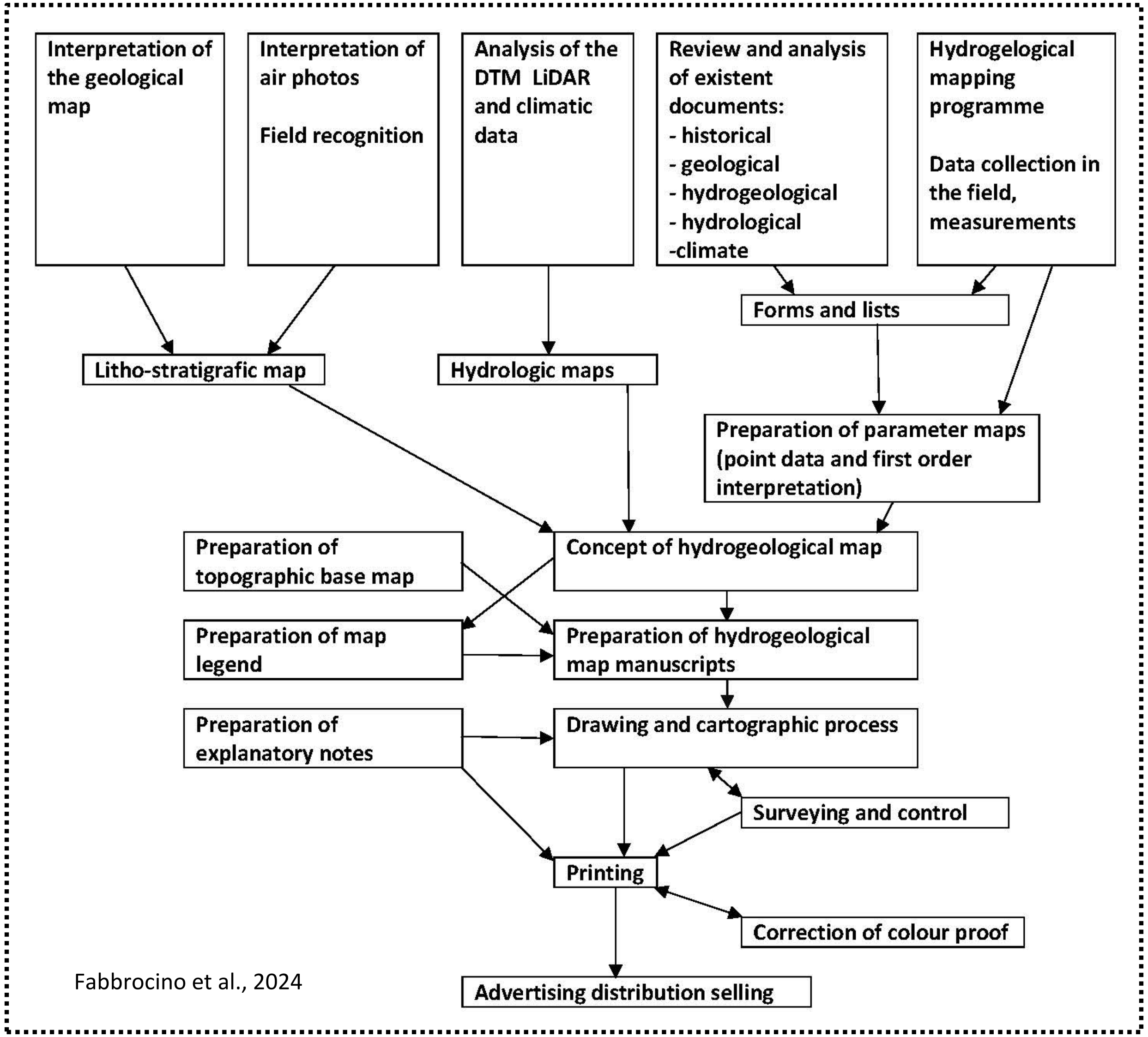
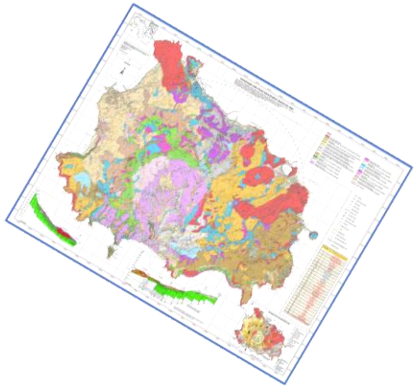
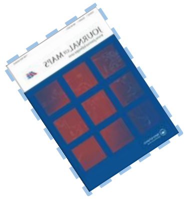






The first hydrogeological map of Ischia Island

Groundwater and active volcanic area

Geohydrologic units of Ischia Island

Geological map and data

C.A.R.G. Project (National Geologicla CARtography)

Piezometric and geochemical data

Archives of local and regional public authorities

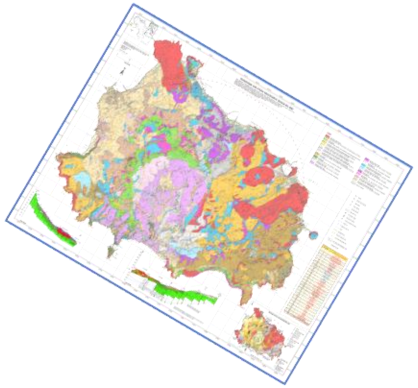
Meteorological time-series data

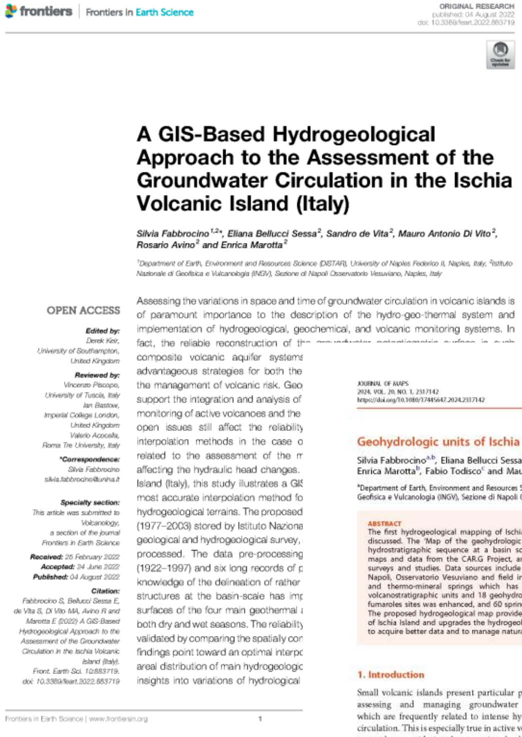
Hydrological Annals -National Hydrographic and Mareographic Service

Long records of piezometric water levesl

Hydrological Annals -National Hydrographic and Mareographic Service

New volcanological and hydrogeological surveys




frontiers | Frontiers in Earth Science

ORIGINAL RESEARCH

A GIS-Based Hydrogeological Approach to the Assessment of the Groundwater Circulation in the Ischia Volcanic Island (Italy)

Silvia Fabbrocino, Eliana Bellucci Sessa, Sandro de Vita, Mauro Antonio Di Vito, Rosario Avino and Enrica Marotta

OPEN ACCESS

Fabbrocino et al., 2022

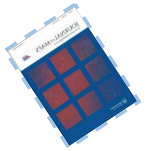

JOURNAL OF MAPS

OPEN ACCESS

Geohydrologic units of Ischia Island (Southern Tyrrhenian Sea, Italy)

1. Introduction

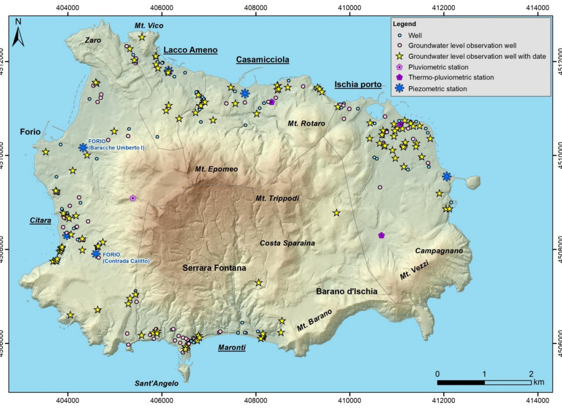
Fabbrocino et al., 2024

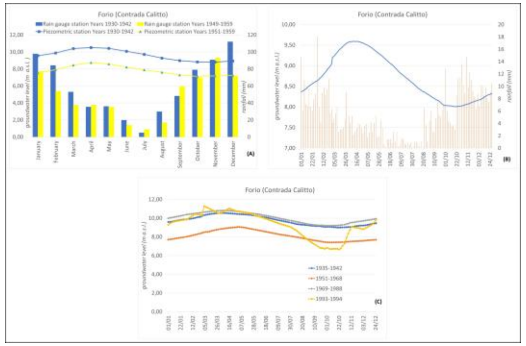


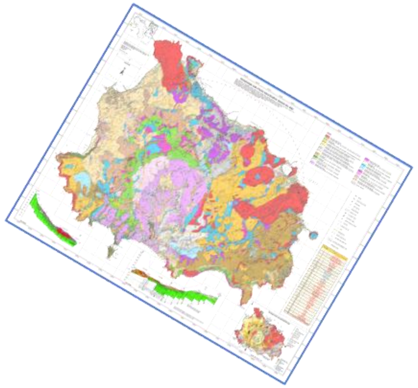
The first hydrogeological map of Ischia Island

Groundwater and active volcanic areas

Volcanic islands and hydrogeological database







Rainfall

Geochemical data

Piezometric water levels

Gaining novel insights;

Developing and enhancing predictive models for climate change adaptation and mitigation;

Testing and verifying models;

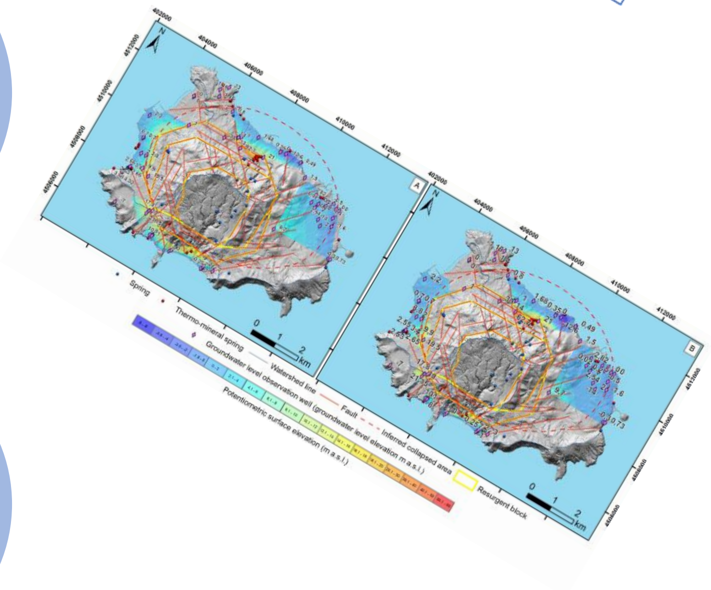
Reducing uncertainties in probabilistic models;

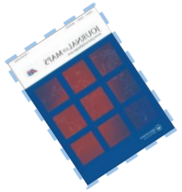
Inspiring new simulation models, including new data-driven methods

Pumping test

Spring discharges

Stratigraphical logs





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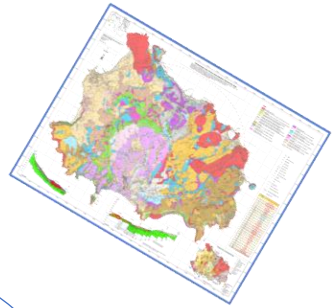
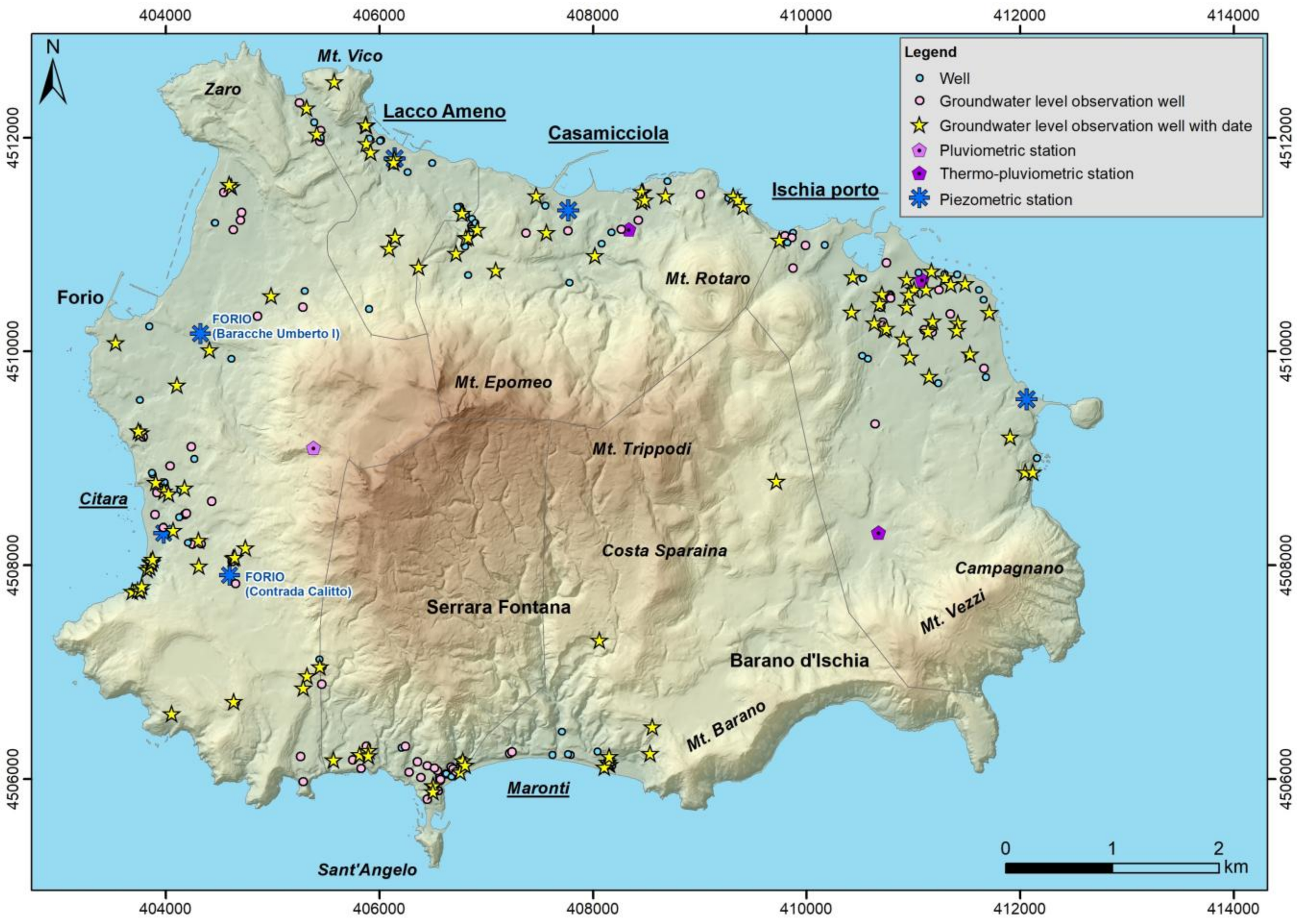
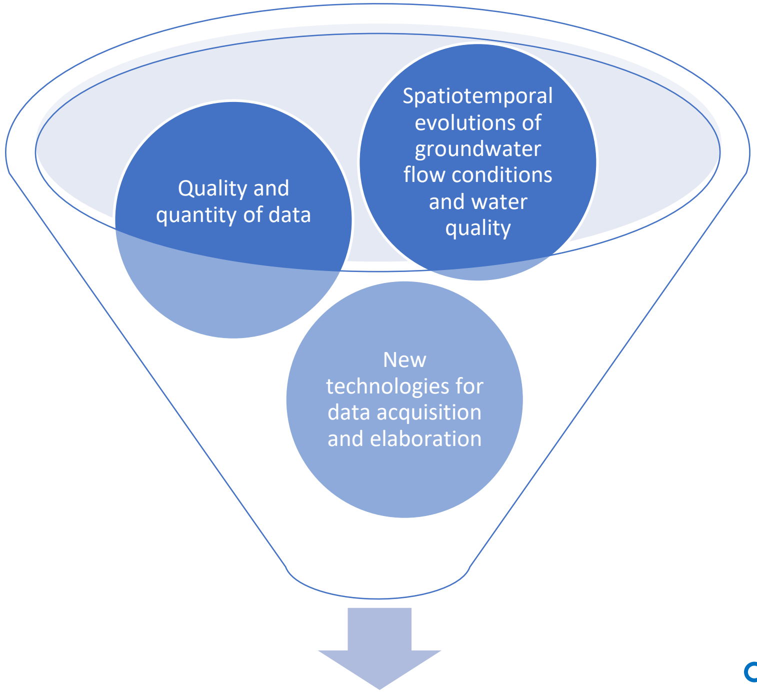




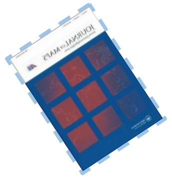


Design of monitoring networks

Resource and risk management

INGV-GIS groundwater database of Ischia

Fabbrocino et al., 2022



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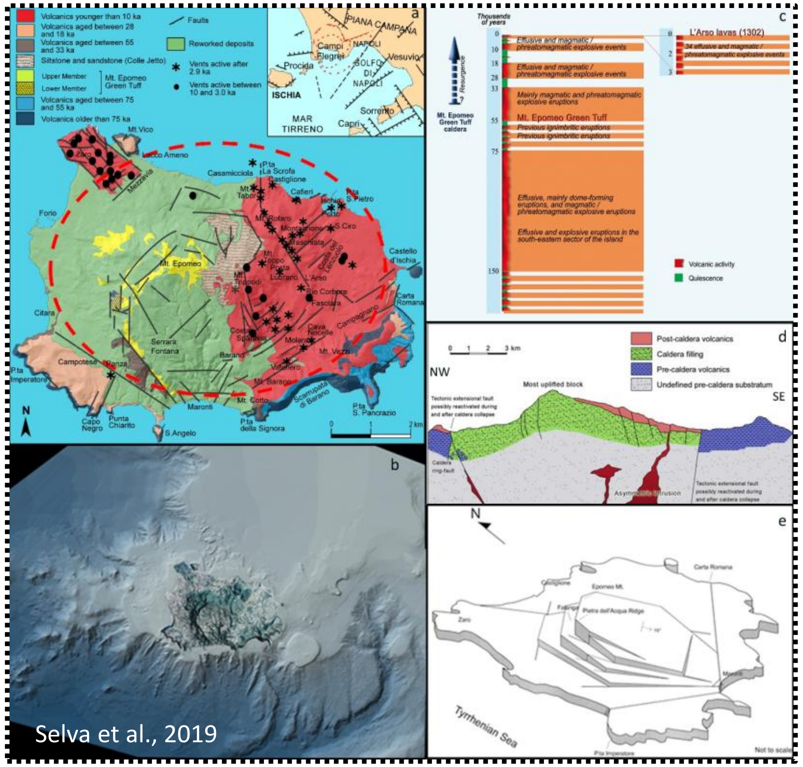
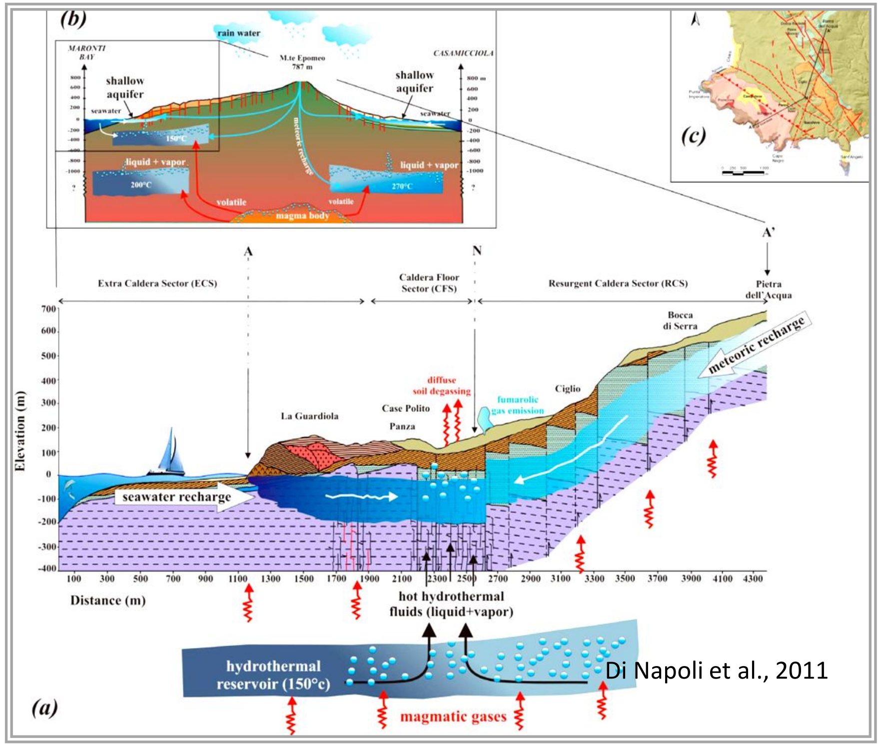
Groundwater and active volcanic areas

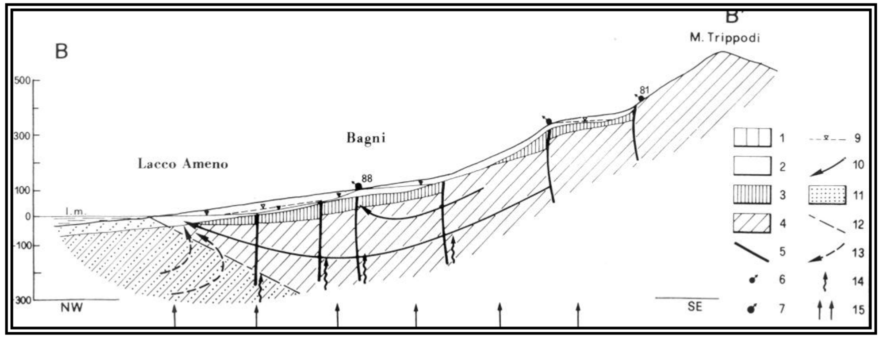
Complex aquifer systems



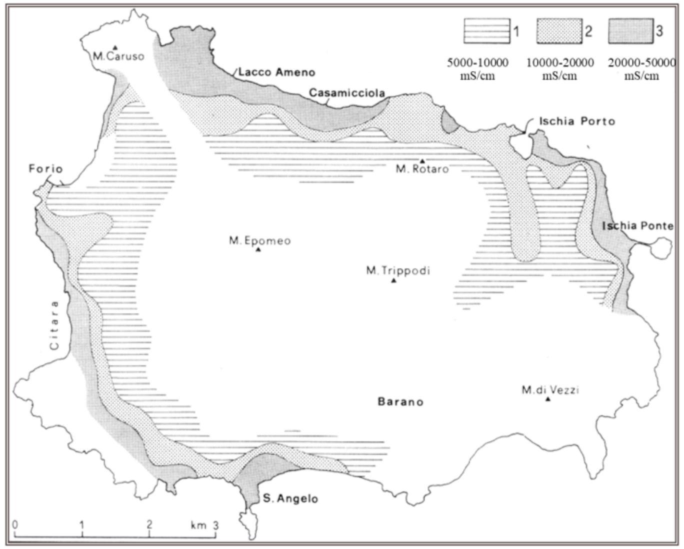
Selva et al., 2019



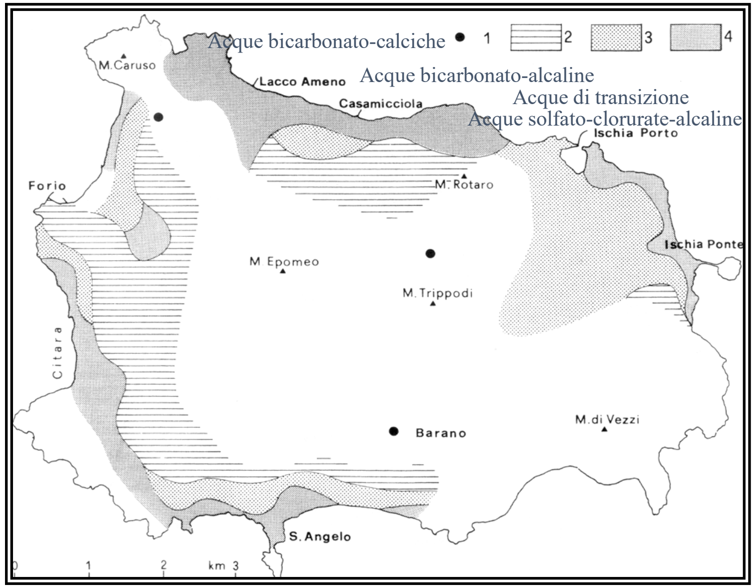
Di Napoli et al., 2011



The first hydrogeological map of Ischia Island



Celico et al., 1999



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Groundwater and active volcanic areas

Hydrothermal System

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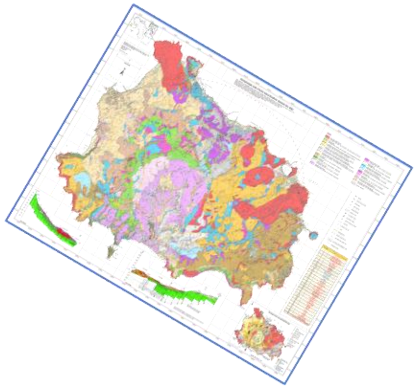


Hydrogeological model

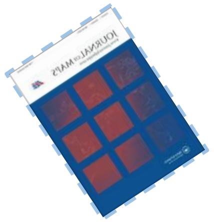
Hydrothermal flowpaths

Is the data quality and quantity suitable for this task and processing?

What are ways to use existing data, which are incomplete and sparse, to aid in understanding changes in flow conditions and resource quality over time?

Can we improve their use to plan more effective monitoring networks for mitigating and managing extreme events that we are increasingly exposed to?

In what ways can new technologies assist in the acquisition, processing, and interpretation of data?



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The first hydrogeological map of Ischia Island

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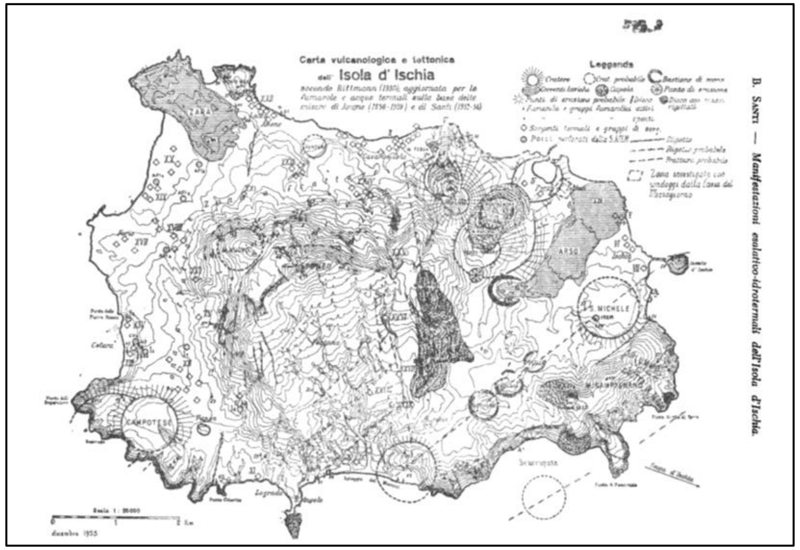
CONSIGLIO NAZIONALE DEI GEOLOGI

Groundwater and active volcanic areas

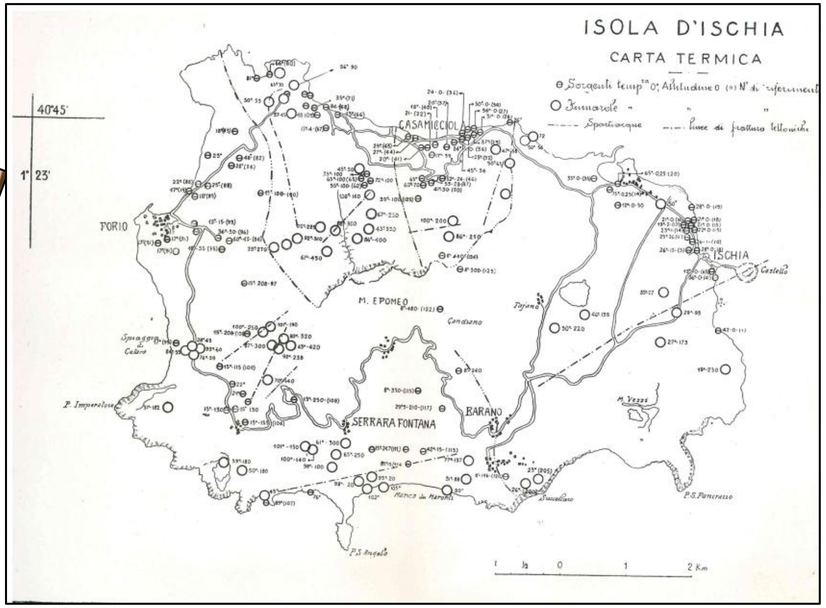
Springs and fumaroles

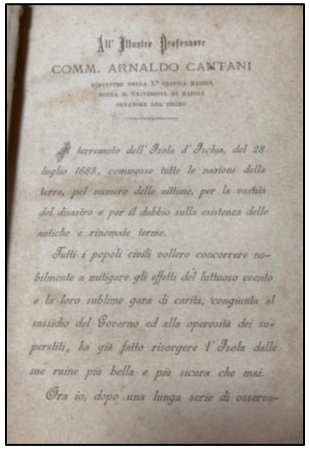


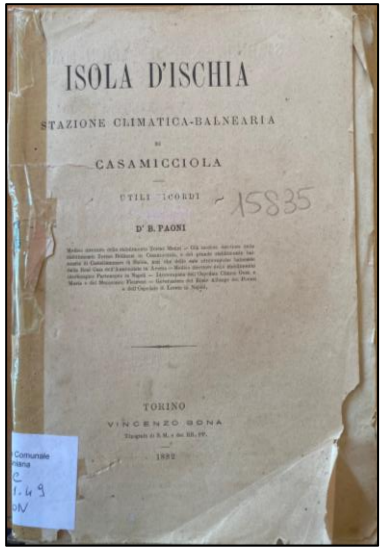

DE RIMEDI NATVRALI CHE SONO NELL'ISOLA DI PITHECVSA; HOGGI DETTA ISCHIA. LIBRI DVE. DI GIVLIO IASOLINO Filosofo, & Medico in Napoli.
Conde tauole copiose.
All' Illustriss. & Eccellentiss. Sig. D. GERONIMA Colonna, d'Aragona.
CON LICENZA, E PRIVILEGIO.
In Napoli Appresso Giuseppe Cacchij, M.D.LXXXVIII.


DESCRIZIONE DELLE ACQUE TERMO-MINERALI E DELLE STUFE DELL'ISOLA D'ISCHIA,
STEFANO CHEVALLEY DE RIVAZ,
DA MICHELANGIOLO ZICCARDI.
NAPOLI,
1838.

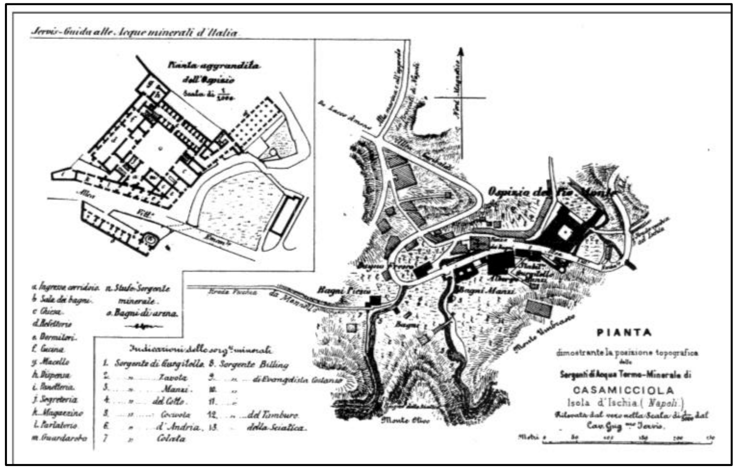

GIULIO GRABLOVITZ E GLI STUDI IDROLOGICI NELL'ISOLA D'ISCHIA




All' Illustre Professore
COMM. ARNALDO CANTANI
Il terremoto dell' Isola d'Ischia, del 28 luglio 1883, commosse tutte le nazioni della terra, pel numero delle vittime, per la vastità del disastro e per il dubbio sulla esistenza delle antiche e rinomate terme.
Tutti i popoli civili vollero concorrere nobilmente a mitigare gli effetti del luttuoso evento e la loro sublime gara di carità, congiunta al sussidio del Governo ed alla operosità dei superstiti, ha già fatto risorgere l'Isola dalle sue ruine più bella e più sicura che mai.
Ora io, dopo una lunga serie di osserva-


ISOLA D'ISCHIA
STAZIONE CLIMATICA-BALNEARIA
DI
CASAMICCIOLA
UTILI RICORDI
D[R] B. PAONI
TORINO
VINCENZO BONA
1882


Sorgente del Gurgitiello in Casamicciola Terme



The first hydrogeological map of Ischia Island

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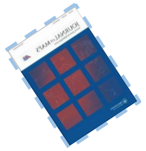

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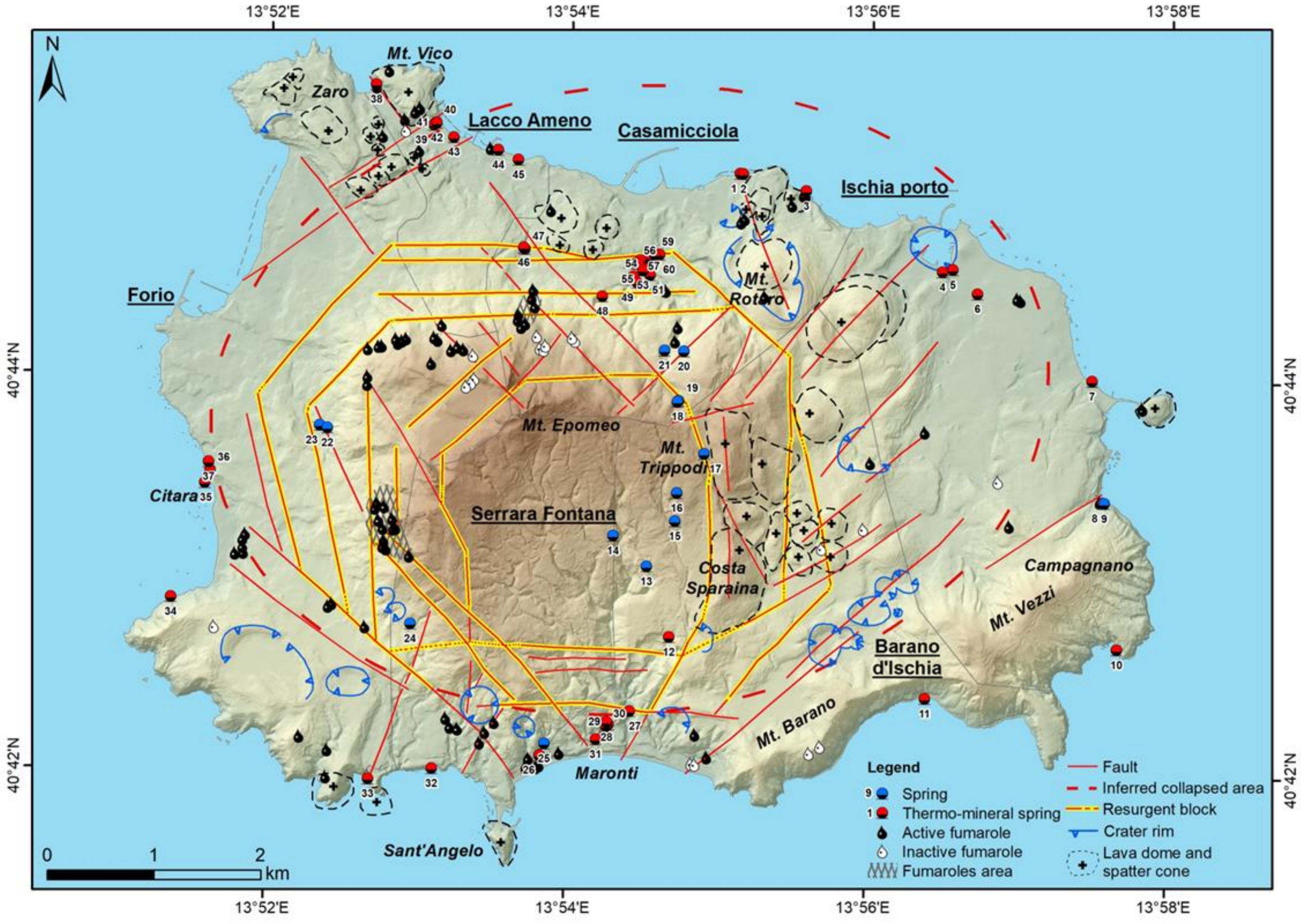
Groundwater and active volcanic areas

Springs and fumaroles



The first hydrogeological map of Ischia Island

Type of unrest	Geochemical signal	Indication
Unrest	CO_2 flux above background	Changes in deep degassing dynamics
	Increase in T of hot springs and/or fumaroles	Increased heat input
	Changes in H_2O/CO_2 ratios in fumaroles	Changes in water/gas ratio
	Appearance of new fumaroles and/or hot springs	Aerial extension of activity
Magmatic unrest	Appearance of acidic gases (SO_2, HCl, HF)	Changes in mid- to shallow magma dynamics
	T fumarole >119 °C	Remobilisation of sulphur
	SO_2 flux > X t/d	SO_2 flux above background, volcano-dependent
	Increase in CO_2/SO_2 ratio	Arrival of an undegassed magma at depth
	Extreme increase in T fumaroles (>300 °C)	Towards magmatic T
Magmatic eruption	Decreasing CO_2/SO_2 ratios after increase	More superficial magma degassing
	Increase in Cl, Br, F concentrations in hot springs/pools	Input of highly soluble acidic gases
	Decrease in H_2O/CO_2 and/or H_2S/SO_2 and/or SO_2/HCl ratios	More gas with a more magmatic signature
Hydrothermal unrest	New fumaroles	Aerial extension of activity
	Anomalous glacier defrosting	Sudden removal of water mass… lahars
	Water to vapour transition	Pushing vapour front from below
	Changes in hydrothermal features	Variations or aerial extension of activity
	Increase in B and/or NH_4 in waters	Input of vapour
	Increase in CH_4/CO_2 in fumaroles	A more hydrothermal signature in fumaroles
	Variations in phreatic level in aquifers	Pushing vapour front from below
Hydrothermal eruption	120 °C < T fumarole <200 °C	Self-sealing by a change in S viscosity
	Extension of alteration areas or fumarolic fields	Aerial extension of activity
	Appearance of muddy pools	Clearing bugs and vents, unplugging
	Boiling/bubbling of pools that previously didn't	Rising vapour front and/or extra heating and degassing

Rouwet et al., 2017

Thermal springs, fumaroles and clay deposits are the traces of deep hydrothermal conditions

The heat and gases released by magma affect the overlying aquifer system which is fed mainly by meteoric water, but the conditions of shallower groundwater flow may attenuate or obliterate the signal that the volcanic system provides

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Groundwater and active volcanic areas

Springs and fumaroles

Number ID	Name	Classification	Elevation (m a.s.l.)	Temperature (°C)	Discharge (l/s)
1	Casa Coma	Thermo-mineral spring	0.13	from 17 to 56 (1936-1939); from 18 to 70 (1952-1954) (Santi,1955)	
2	Sorgente della Scrofa	Thermo-mineral spring	0.00	from 17 to 56 (1936-1939); from 18 to 70 (1952-1954) (Santi,1955)	
3	Sorgente di Castiglione	Thermo-mineral spring	0.00	37.5-40 (Chevalley De Rivaz, 1837, Morgera, 1890); 30-40 (Piscopo et al., 2020)	<1 (Piscopo et al., 2020)
4	Fornello and Fontana Springs	Thermo-mineral spring	4.09	55 (Morgera, 1890); 52 Fornello and 54 Fontana (Rebuffat, 1900); 55-58 (Iovene, 1934); 46-63 (Santi, 1955), 54-62 (Buchner, 1959); 50-60° (Rittmann & Gottini, 1980)	0.86 Fontana and 1.48 Fornello (Morgera, 1890; Iovene,1934); 2.31 (Rittmann & Gottini, 1980)
5	Stabilimento Militare	Thermo-mineral spring	2.59	from 58 to 63 (Santi,1955)	
6	Felix	Thermo-mineral spring	1.48	38 (Piscopo et al., 2020)	2 (Piscopo et al., 2020)
7	Bagno del Sasso	Thermo-mineral spring	0.00	36 (Santi, 1955)	
8	Carta Romana	Thermo-mineral spring	0.00	42 (Iovene, 1934) 32 (Piscopo et al. 2020); 35.5 (July 15, 2020)	<1 (Piscopo et al. 2020)
9	Campagnano	Spring	0.16		
10	Cefaglioli	Thermo-mineral spring	0.00		

"A total of 60 spring/thermal spring locations were identified/rediscovered...Groundwater discharges from the volcanic aquifer system occur at an altitude that goes from 0 to about 451 m asl and the flow rate is generally a few litres per second.

The total spring flow (clearly outdated) appears to be about 10% of the estimated aquifer recharge (about 340-380 l/s; Piscopo et al., 2020a); at a basin scale, coastal groundwater discharge accounts the main natural overflow.

The areal distribution of springs and fumaroles (elevation between 0 and 557 m asl) highlights that they are commonly associated with main morpho-structural elements. They take place largely (about 93%) along the coastline and/or the caldera boundaries as well as along the main faults around the resurgent block, becoming fingerprints of the basin-scale hydrogeological processes; they reveal the geological/volcanological features that create transmissive pathways or barriers to flow. "

The first hydrogeological map of Ischia Island

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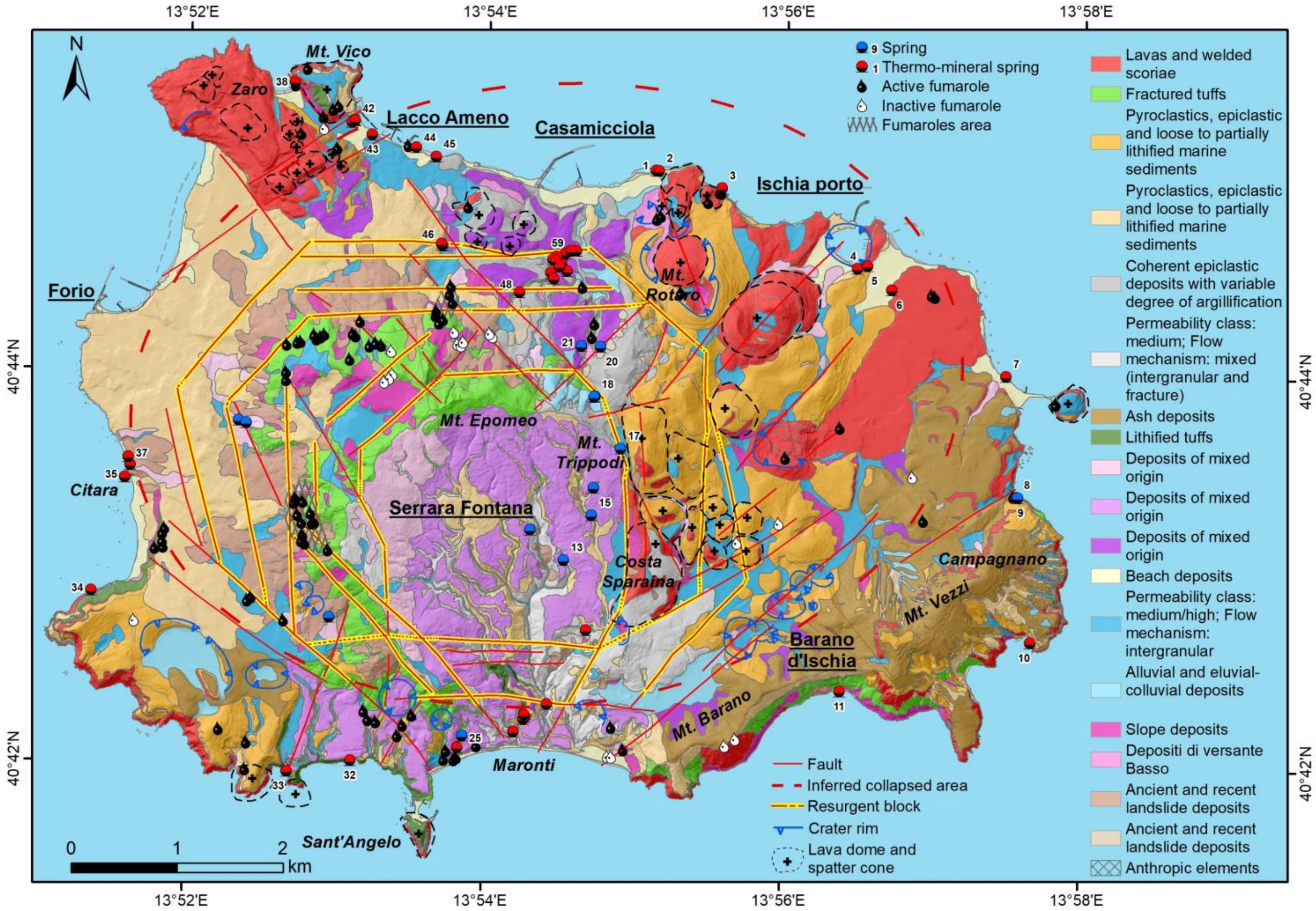
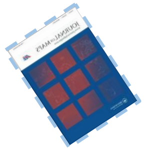
CONSIGLIO NAZIONALE DEI GEOLOGI

Groundwater and active volcanic areas

Springs and fumaroles



"…the main faults of the resurgent block and the caldera boundaries should be related to barriers to horizontal groundwater flow, even if they act as vertical conduits for deep groundwater flow. In addition, the vertical displacement and the pattern of identified vents often constraint the juxtaposition of lithostratigraphic units with contrasting permeabilities."



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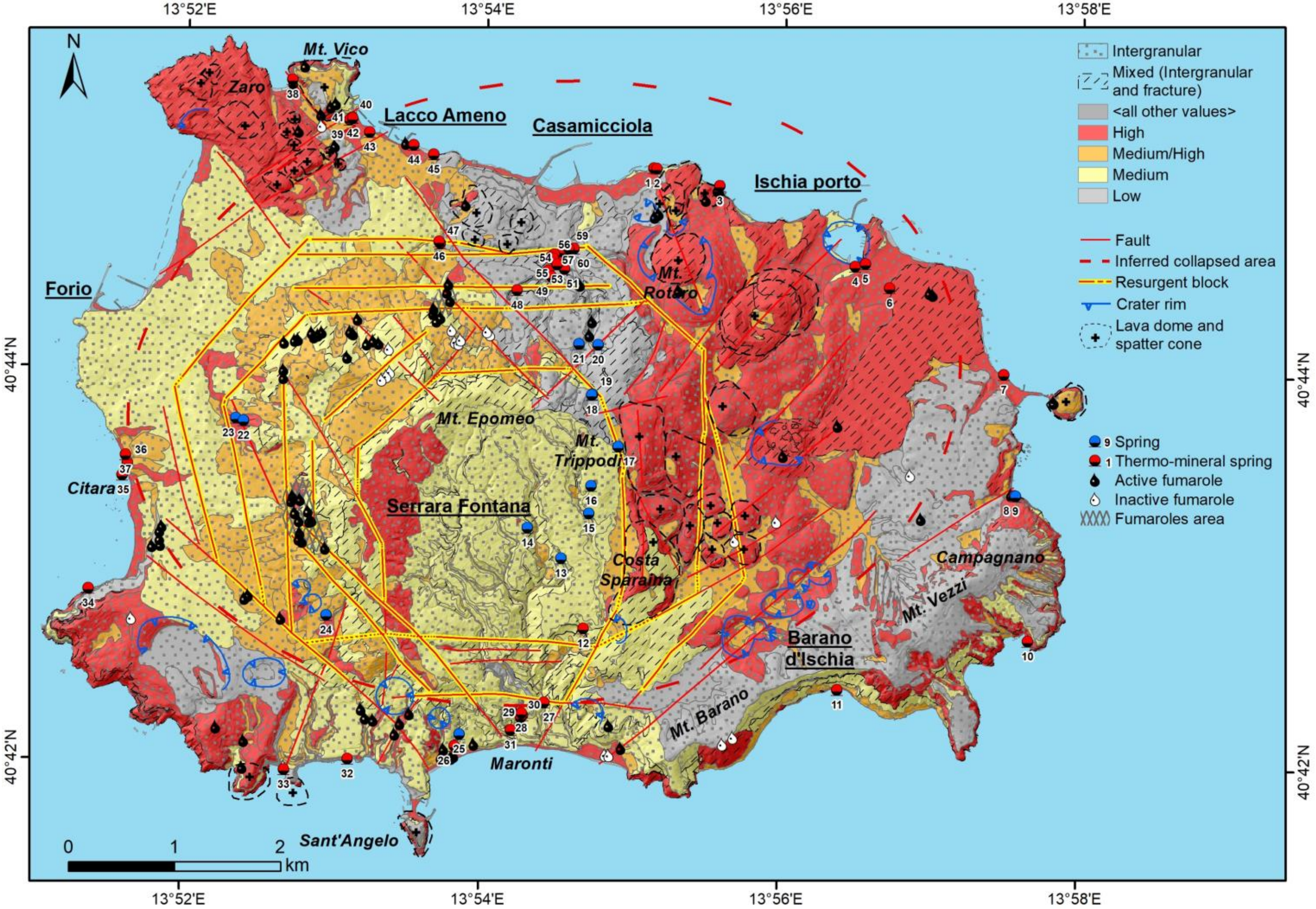
The first hydrogeological map of Ischia Island

Groundwater and active volcanic areas

Geohydrologic units and hydrostratigraphic sequence

	GEOHYDROLOGIC UNITS					
SEDIMENTARY QUATERNARY DEPOSITS	Beach deposits (Permeability class: high; Flow mechanism: intergranular) (12)	Alluvial and eluvial-colluvial deposits (Permeability class: medium/high; Flow mechanism: intergranular) (13)	Slope deposits (Permeability class: medium/high; Flow mechanism: intergranular) (15)	Ancient and recent landslide deposits (Permeability class: medium/high; Flow mechanism: intergranular) (17)	Deposits of mixed origin (Permeability class: high; Flow mechanism: intergranular) (9)	
					Deposits of mixed origin (Permeability class: medium; Flow mechanism: intergranular) (10)	
		Alluvial and eluvial-colluvial deposits (Permeability class: low; Flow mechanism: intergranular) (14)	Slope deposits (Permeability class: low; Flow mechanism: intergranular) (16)	Ancient and recent landslide deposits (Permeability class: low; Flow mechanism: intergranular) (18)	Deposits of mixed origin (Permeability class: low; Flow mechanism: intergranular) (11)	
PHASE 5 - POST CALDERA ACTIVITY: RENEWAL OF CALDERA RESURGENCE AND VOLCANISM (10KY-1302 A.D.)	Lavas and welded scoriae (Permeability class: high; Flow mechanism: mixed) (1)	Beach deposits (Permeability class: high; Flow mechanism: intergranular) (12)	Pyroclastics, epiclastic and loose to partially lithified marine sediments (Permeability class: high; Flow mechanism: intergranular) (3)			
			Pyroclastics, epiclastic and loose to partially lithified marine sediments (Permeability class: medium; Flow mechanism: intergranular) (4)	Deposits of mixed origin (Permeability class: medium; Flow mechanism: intergranular) (10)	Coherent epiclastic deposits with variable degree of argillification (Permeability class: medium; Flow mechanism: mixed) (6)	
				Deposits of mixed origin (Permeability class: low; Flow mechanism: intergranular) (11)	Coherent epiclastic deposits with variable degree of argillification (Permeability class: low; Flow mechanism: mixed) (5)	Ash deposits (Permeability class: low; Flow mechanism: intergranular) (7)
PHASE 4 – POST CALDERA ACTIVITY: RENEWAL OF VOLCANISM (28-18 KY)	Lavas and welded scoriae (Permeability class: high; Flow mechanism: mixed) (1)		Pyroclastics, epiclastic and loose to partially lithified marine sediments (Permeability class: high; Flow mechanism: intergranular) (3)			
			Pyroclastics, epiclastic and loose to partially lithified marine sediments (Permeability class: medium; Flow mechanism: intergranular) (4)			
						Lithified tuffs (Permeability class: low; Flow mechanism: intergranular) (8)
PHASE 3 – POST CALDERA ACTIVITY: BEGINNING OF MT. EPOMEO RESURGENCE (55-33 KY)			Pyroclastics, epiclastic and loose to partially lithified marine sediments (Permeability class: high; Flow mechanism: intergranular) (3)			
	Fractured tuffs (Permeability class: medium; Flow mechanism: mixed) (2)		Pyroclastics, epiclastic and loose to partially lithified marine sediments (Permeability class: medium; Flow mechanism: intergranular) (4)	Deposits of mixed origin (Permeability class: medium; Flow mechanism: intergranular) (10)		
					Coherent epiclastic deposits with variable degree of argillification (Permeability class: low; Flow mechanism: mixed) (5)	Lithified tuffs (Permeability class: low; Flow mechanism: intergranular) (8)
PHASE 2 – CALDERA FORMATION AND FILLING (60-55 KY)	Lavas and welded scoriae (Permeability class: high; Flow mechanism: mixed) (1)		Pyroclastics, epiclastic and loose to partially lithified marine sediments (Permeability class: high; Flow mechanism: intergranular) (3)			
	Fractured tuffs (Permeability class: medium; Flow mechanism: mixed) (2)		Pyroclastics, epiclastic and loose to partially lithified marine sediments (Permeability class: medium; Flow mechanism: intergranular) (4)			
					Coherent epiclastic deposits with variable degree of argillification (Permeability class: low; Flow mechanism: mixed) (5)	Lithified tuffs (Permeability class: low; Flow mechanism: intergranular) (8)
PHASE 1 – PRE-CALDERA ACTIVITY (>150-73 KY)	Lavas and welded scoriae (Permeability class: high; Flow mechanism: mixed) (1)		Pyroclastics, epiclastic and loose to partially lithified marine sediments (Permeability class: high; Flow mechanism: intergranular) (3)			
	Fractured tuffs (Permeability class: medium; Flow mechanism: mixed) (2)		Pyroclastics, epiclastic and loose to partially lithified marine sediments (Permeability class: medium; Flow mechanism: intergranular) (4)			
						Lithified tuffs (Permeability class: low; Flow mechanism: intergranular) (8)

- ✓ high permeability, $k>10^{-3}$ m/s;
- ✓ medium permeability, $10^{-4}<k<10^{-3}$ m/s;
- ✓ low permeability, $10^{-9}<k<10^{-4}$ m/s



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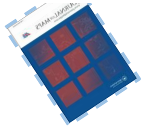
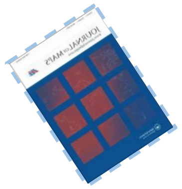


Groundwater and active volcanic areas

Geohydrologic unit and hydrostratigraphic sequence – Appendix 1

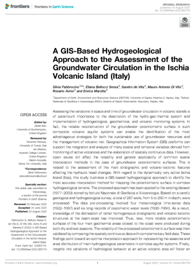
- Eighteen geohydrologic units (a lithostratigraphic unit, or a group of lithostratigraphic units, that by virtue of its hydraulic properties has a dominant flow mechanism and a small range of permeability values) have been identified on Ischia Island;
- They classify the lithostratigraphic units according to their capacity to transmit, store and yield water (aquifer or confining unit) and identify the basic unit of the hydrogeological map
- Their extension, structure, and geometry characterize the aquifer systems and affect/depict the groundwater flow
- The identification of these geohydrologic units reveals the impact of volcano-tectonic features on the groundwater circulation

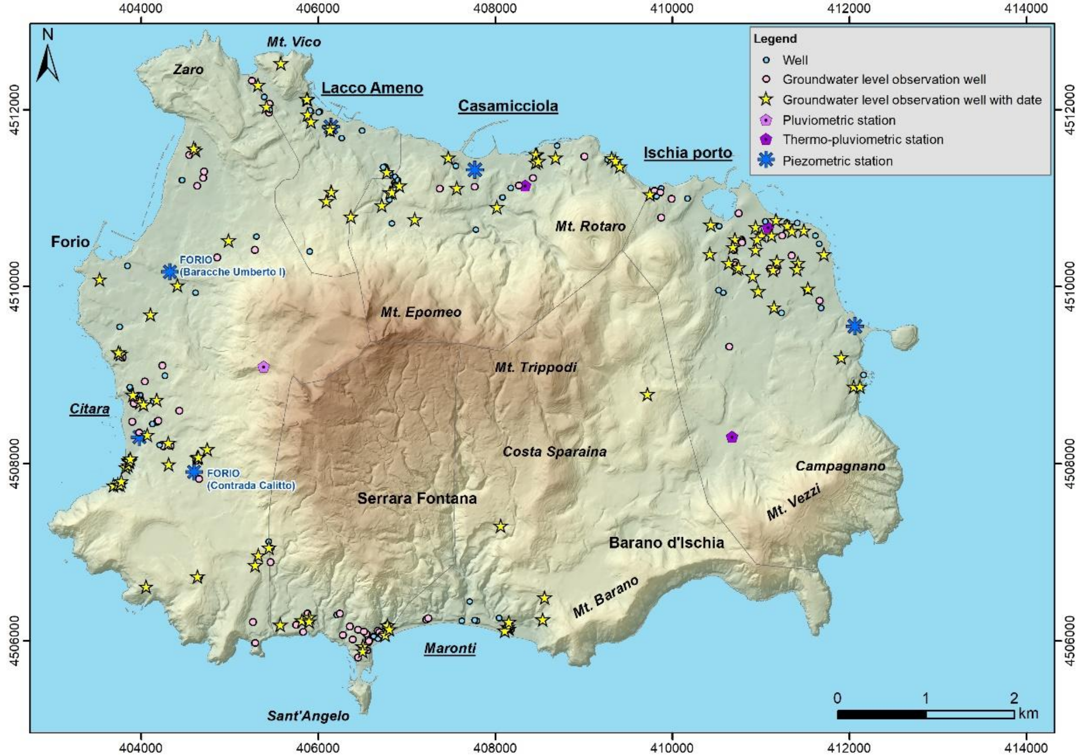
- *The lithostratigraphical unit name and a brief lithological description give the combination with the CAR.G Project formations (National Geological CARtography) (Sbrana & Toccaceli, 2011; Sbrana et al., 2018) and /or lithostratigraphic units recognized in de Vita et al., 2010;*
- *The permeability index describes the predominant flow mechanism, specifically intergranular, fracture or mixed (intergranular and fracture), and the attributed permeability class;*



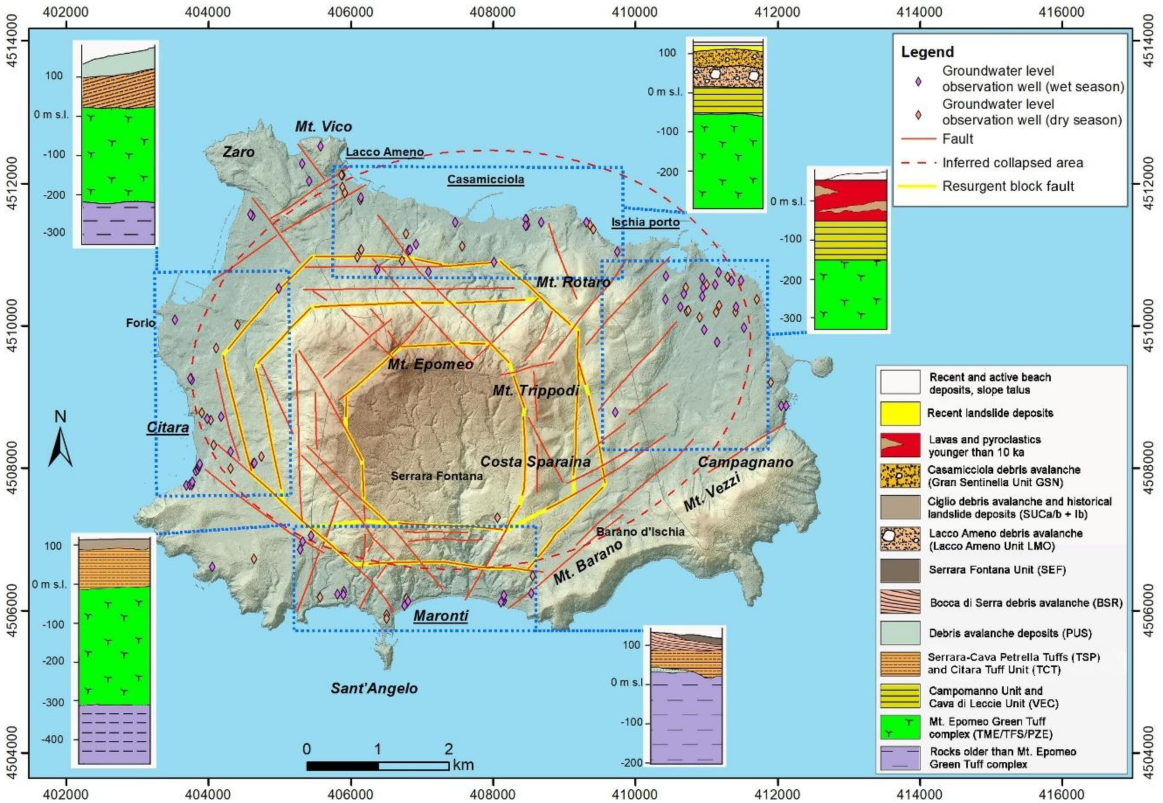
Groundwater and active volcanic areas

Hydrodynamic setting



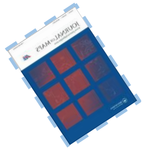


INGV-GIS groundwater database of Ischia. Available site descriptive information includes well location and groundwater level data. The National Hydrographic and Mareographic monitoring networks is also indicated. DEM derives from the Regional Technical Map, scale 1:5000



Stratigraphical and structural sketch map of Ischia. Available groundwater level datasets are shown; site descriptive information includes well depths and stratigraphic logs. Blue dashed lines highlight the four distinct sectors used for the reconstruction of a reliable potentiometric surface. Stratigraphic data are based on drilling information.

The first hydrogeological map of Ischia Island



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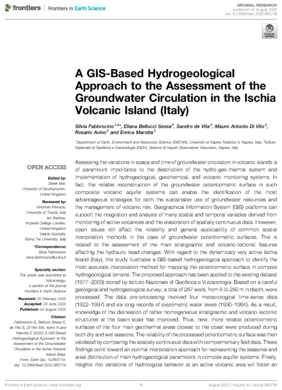
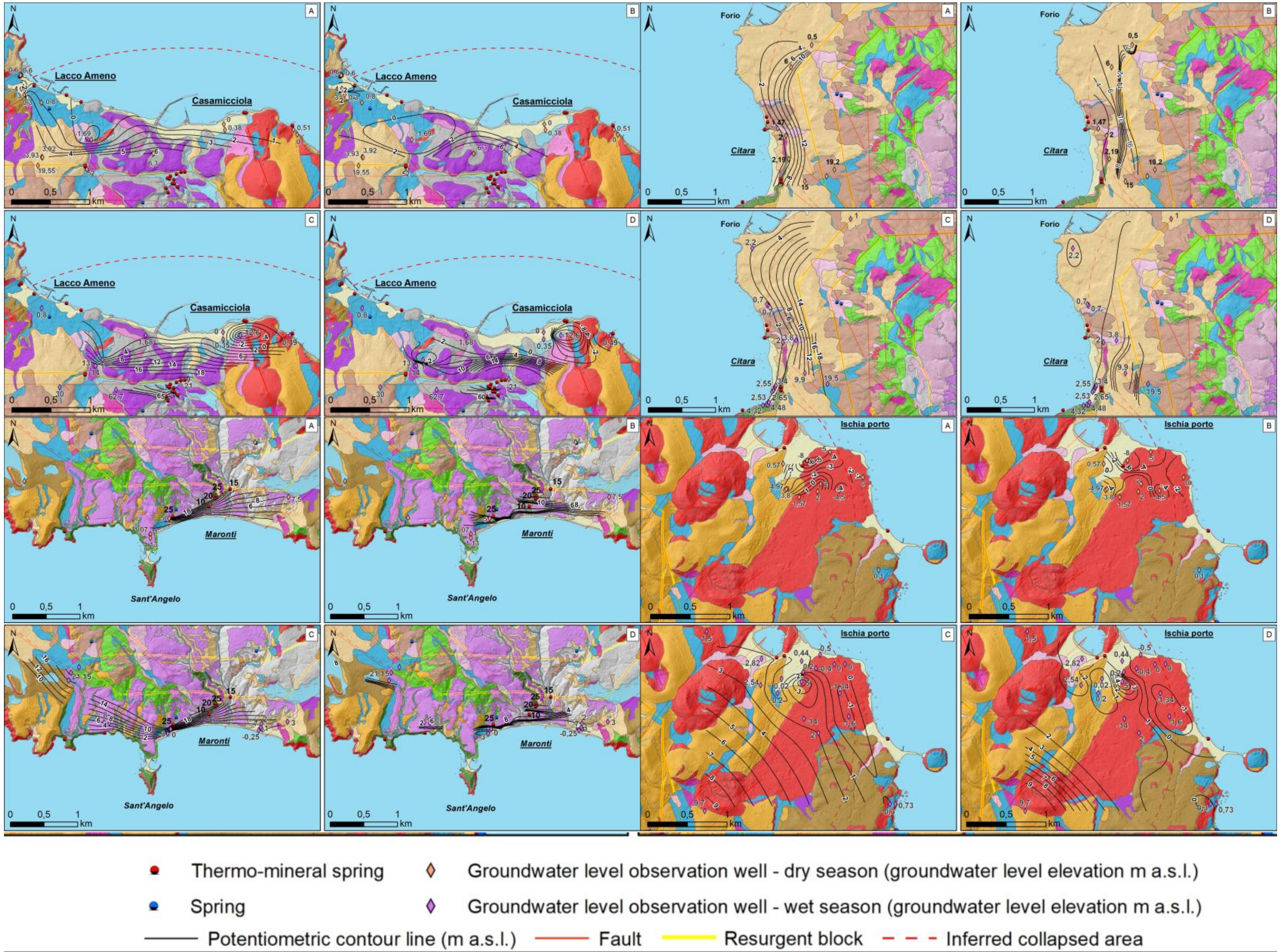
Groundwater and active volcanic areas

Hydrodynamic setting

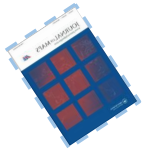




The first hydrogeological map of Ischia Island

Piezometric surface map of the four selected sectors: Casamicciola-Lacco Ameno, Citara, Maronti e Ischia Porto.

A) NaN interpolation, B) IDW interpolation (dry season; C) NaN interpolation, D) IDW interpolation (wet season)



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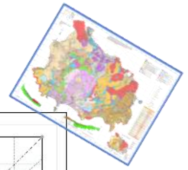
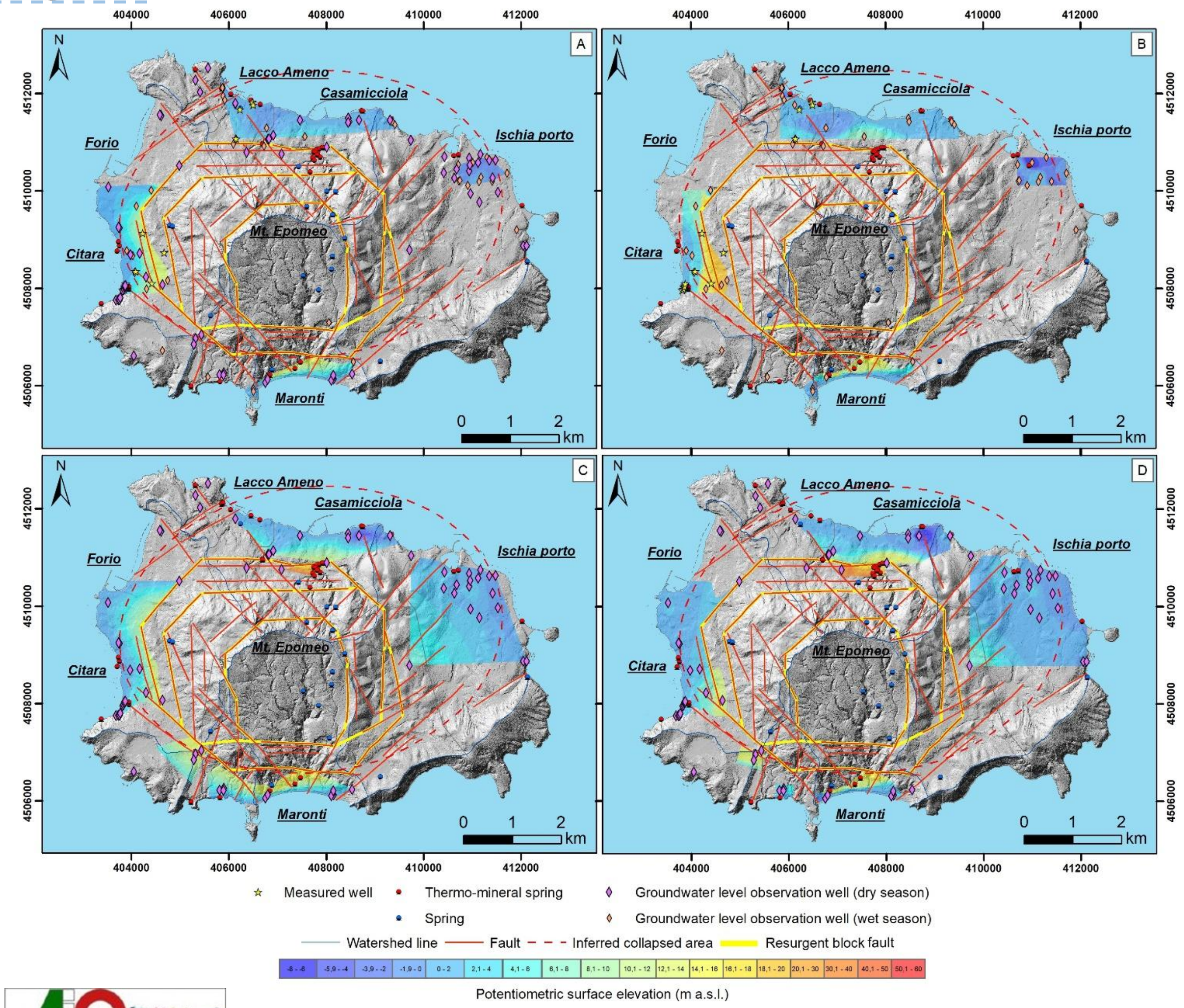
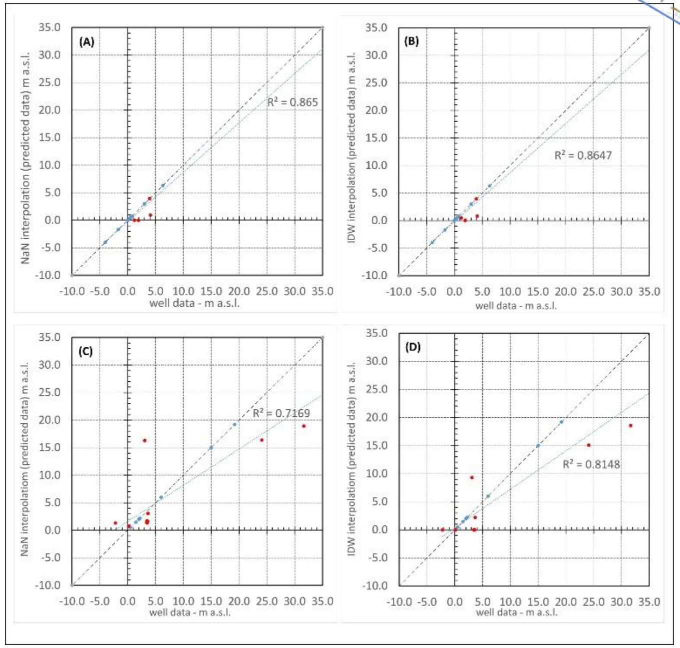
Groundwater and active volcanic areas

Hydrodynamic setting



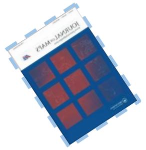



A GIS-Based Hydrogeological Approach to the Assessment of the Groundwater Circulation in the Ischia Volcanic Island (Italy)



Correlation between the measured groundwater level (well data) and the predicted values (derived from the interpolation model) during the dry season in the Casamicciola-Lacco Ameno sector: (A) NaN interpolation; (B) IDW interpolation; and in the Citara sector: (C) NaN interpolation; (D) IDW interpolation. Blue dots correspond to available data; red dots to complementary field groundwater level measurements

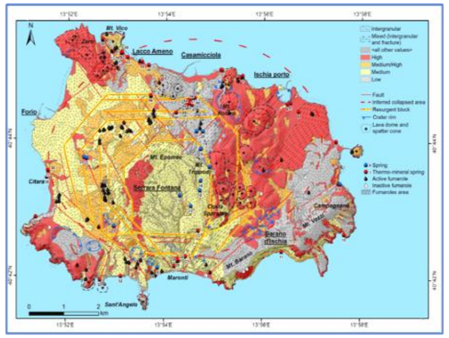
Structural sketch map of Ischia Island and reconstructed piezometric surfaces of the four main geothermal areas: (A) NaN interpolation (dry season) and (B) IDW interpolation (dry season); (C) NaN interpolation and (D) IDW interpolation (wet season). The geometry of datasets used for the interpolation is shown; the location of wells used for the validation is reported, as well as all springs/thermo-mineral springs surveyed during field activities.



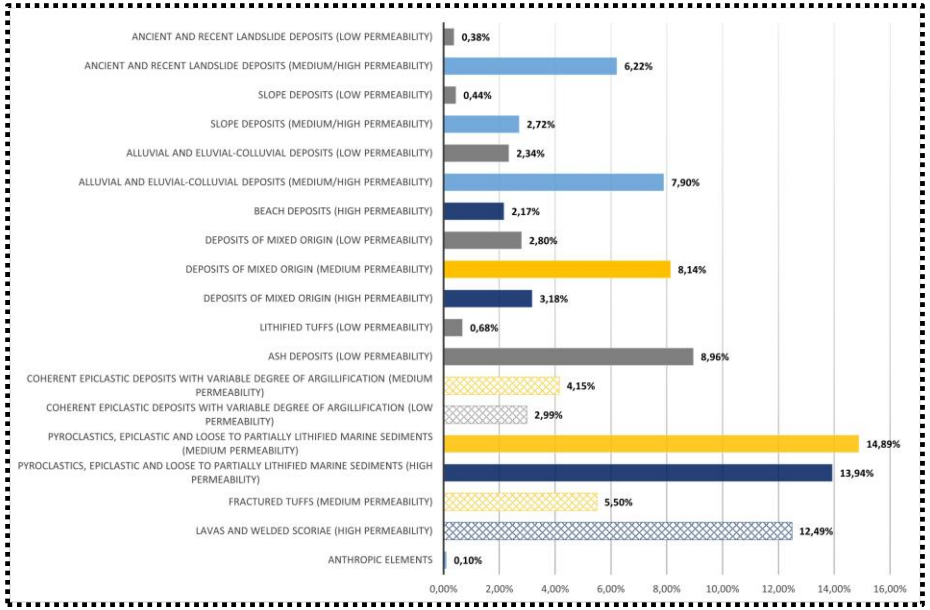
The first hydrogeological map of Ischia Island

Hydrogeological map of Ischia Island

Summary and perspectives



- The geohydrologic units ranging from high to medium/high permeability are the main aquifers
  - Lavas, welded scoriae and fractured tuffs
  - Loose to partially lithified pyroclastic and sedimenatry deposists



- The coherent epiclastic and marine deposits from the main period of stasis and the lithified tuffs confine and constrain the groundwater flow

- The sedimetary Quaternary deposits have a permeability combination that is influenced by the characteristics of their origin
  - They influence the infiltration and runoff processes
  - They control the location of the spring, «*cold water*»
  - They highlight the morpho-structural control of groundwater hydrodynamics

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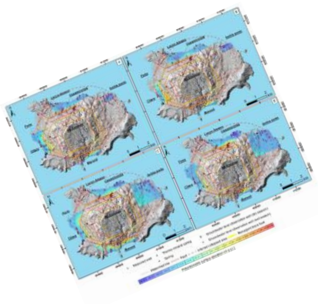
DiSTAR Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse

CONSIGLIO NAZIONALE DEI GEOLOGI

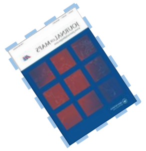
Hydrogeological map of Ischia Island

Summary and perspectives

- Springs and fumaroles take place largely (93%) along the coastline and/or the caldera boundaries as well as along the main faults around the Monte Epomeo resurgent block, revealing the geological/volcanological features that create transmissive pathways or barriers to flow
- The main volcano-tectonic structures (caldera and resurgent block) and eruptive vents control the continuity of the hydrofacies
- The relationship between the caldera/resurgent block and main eruptive vents enables the identification of several different hydrostructures
- The first assessment of the average seasonal fluctuations in the potentiometric surface is about 2 m
- Pumping wells controls the spatiotemporal fluctuations of hydraulic head
- The upgrade of the hydrogeological model, where the so called «basal aquifer» of the shallower volcanic aquifer system, cannot be considered continuous, may assist in hightlining critical issues and improving the hydrogeological, geochemical, seismic and volcanic monitoring system.



A GIS-Based Hydrogeological Approach to the Assessment of the Groundwater Circulation in the Ischia Volcanic Island (Italy)



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The first hydrogeological map of Ischia Island

INGV OSSERVATORIO VESUVIANO
SEZIONE DI NAPOLI

DiSTAR Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse

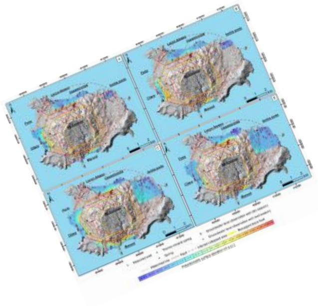
Hydrogeological map of Ischia Island

Summary and perspectives

CONSIGLIO NAZIONALE DEI GEOLOGI

- A rigorous scientific process is followed by the developed cartographic project for a basic geological/hydrogeological map, which satisfies the current and essential socio-economic needs of territories that require managing natural both resources and hazards/risks.

- A technical/hydrogeological map is essential for designing effective territorial/environmental planning and risk management strategies



- Hydrogeological information generated on a scale of 1:10,000 makes it possible to give priority to the recurrence and distribution of the cover deposits, or to detail the geohydrologic unit outcrops which constitute the shallower layers of the subsoil; at the same time, it ensures that the morphostructural setting, which controls the basal aquifer and/or confining units and so the groundwater flow conditions, is not neglected.

A GIS-Based Hydrogeological Approach to the Assessment of the Groundwater Circulation in the Ischia Volcanic Island (Italy)

- As planned, the map of the geohydrologic units at 1:10,000 scale is a useful and innovative technical/decision tool for the implementation of effective strategies in terms of environmental sustainability and socio-economic development

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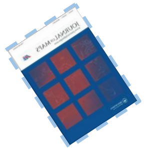
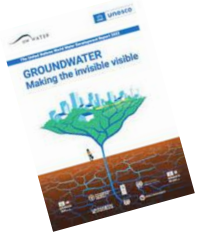


Groundwater and ecosystem services

Science and policy integration

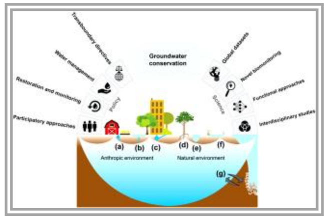


- The water, energy, and food security based on a groundwater sustainable management, well-maintained sanitation systems, sustaining human health, livelihoods, and ecosystems with their valuable services, and climate change mitigation are all pieces of a large and complex puzzle

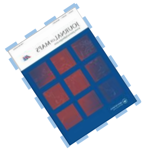
- The way in which societies choose to balance the distribution of groundwater resources between socio-economic activities and natural ecosystems has a strong impact on the quality of life and on suistainable development of the territory

- Investing in cultural education, as well as geological, environmental, social, and economic knowledge of the territory, is crucial

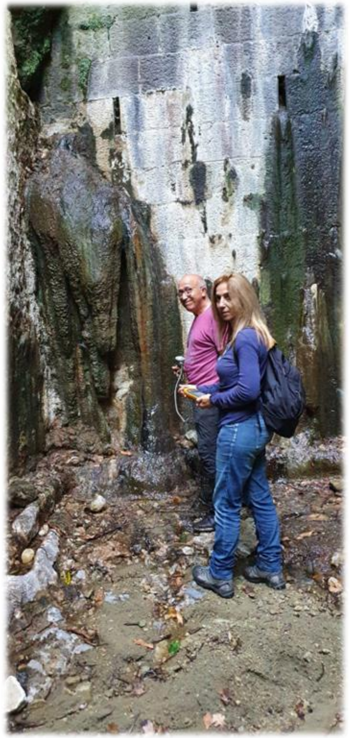
- The arduous challenge is to give an effective and efficient contribution to promote coherent strategies especially between policies for groundwater and the environment, spatial planning and land use



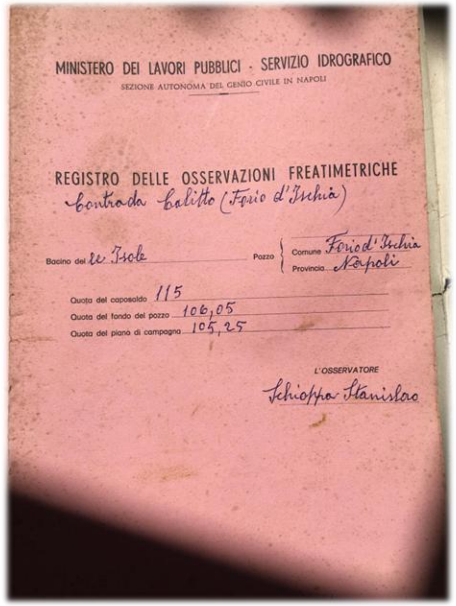
Saccò et al., 2023



The first hydrogeological map of Ischia Island



The first hydrogeological map of Ischia Island



MINISTERO DEI LAVORI PUBBLICI - SERVIZIO IDROGRAFICO
SEZIONE AUTONOMA DEL GENIO CIVILE IN NAPOLI

REGISTRO DELLE OSSERVAZIONI FREATIMETRICHE
Contrada Calitto (Forio d'Ischia)

Bacino del le Isole Pozzo Comune Forio d'Ischia
Provincia Napoli

Quota del caposaldo 115
Quota del fondo del pozzo 106,05
Quota del piano di campagna 105,25

L'OSSERVATORE
Schioppa Stanislao

INGV OSSERVATORIO VESUVIANO
SEZIONE DI NAPOLI

DiSTAR Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse