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ArtEmis

Awareness and resilience through European multi sensor system

A Euratom H2022 research project

- What is artEmis and that is the aim?
- Basic information about the ideas, consortium, the project
- Work Packages in artEmis
- Future wishes and visions

ArtEmis

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Awareness and resilience through European multi sensor system

https://artemisproject.eu

Aim: radon based earthquake forecasting
Starting date: 1st October 2022
Kick-off meeting: 24th -25th October 2022
Duration: 4 years
Budget: 2M €
Participants from: 14 Institutions
Project Coordinator: KTH (Ayşe Ataç Nyberg)

List of participants*

Participant no	Participant organisation name	Short name	Country
1. (Coord)	KUNGLIGA TEKNISKA HOEGSKOLAN	KTH	Sweden
2.	STATNI USTAV RADIACNI OCHRANY v.v.i.	SURO	Czech Republic
3.	ARISTOTELIO PANEPISTIMIO THESSALONIKIS	AUTh	Greece
4.	UNIVERSITA DEGLI STUDI DELL'AQUILA	UNIVAQ	Italy
5.	RadonTec GmbH	RTEC	Germany
6.	GSI HELMHOLTZZENTRUM FUR SCHWERIONENFORSCHUNG GMBH	GSI	Germany
7.	ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA	INGV	Italy
8.	UNIVERSIDAD DE NAVARRA	IESE	Spain
9.	PERIFERIAKI ENOSI DIMON IONION NISON	RUMII	Greece
10.	EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH*	ETH	Switzerland
11.	Comune dell'Aquila	COMUNEAQ	Italy
12.	SORBONNE UNIVERSITE	SU	France
13.	SINTEC SRL	SINTEC	Italy
14.	Joint Research Center – European Commission**	JRC	Belgium

* associated partner

** the JRC will participate in the action, but without the right to charge costs or claim contribution, and will confirm further details of its support at the moment of the Consortium and Grant Agreement negotiations, based on available resources, competences and alignment with the main JRC's research programme priorities.

The connection between earthquakes and increased amount of Radon gas was known since 1927. First recording,which is reported in many publications, and that encouraged research on seismic precursors, was detected before the Tashkent earthquake of 1966 (Ozbekistan, Soviet Union).

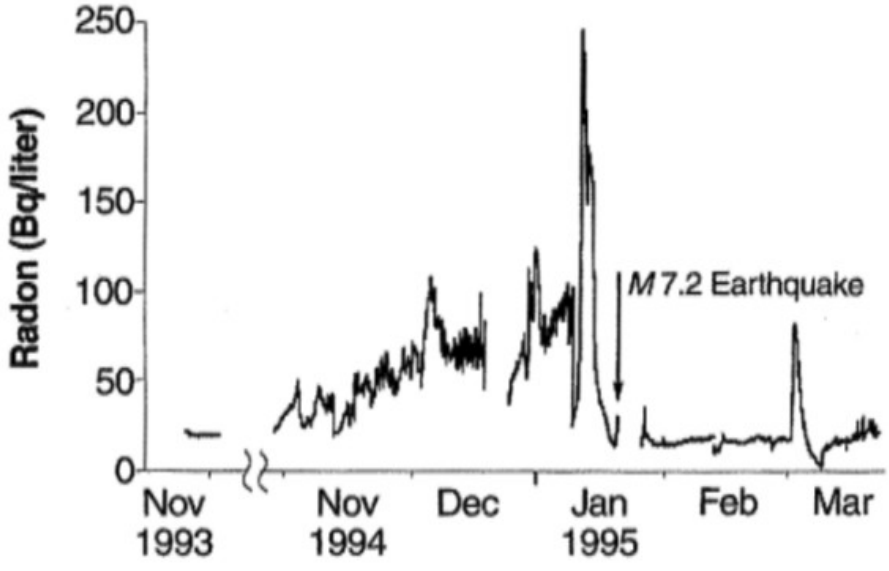


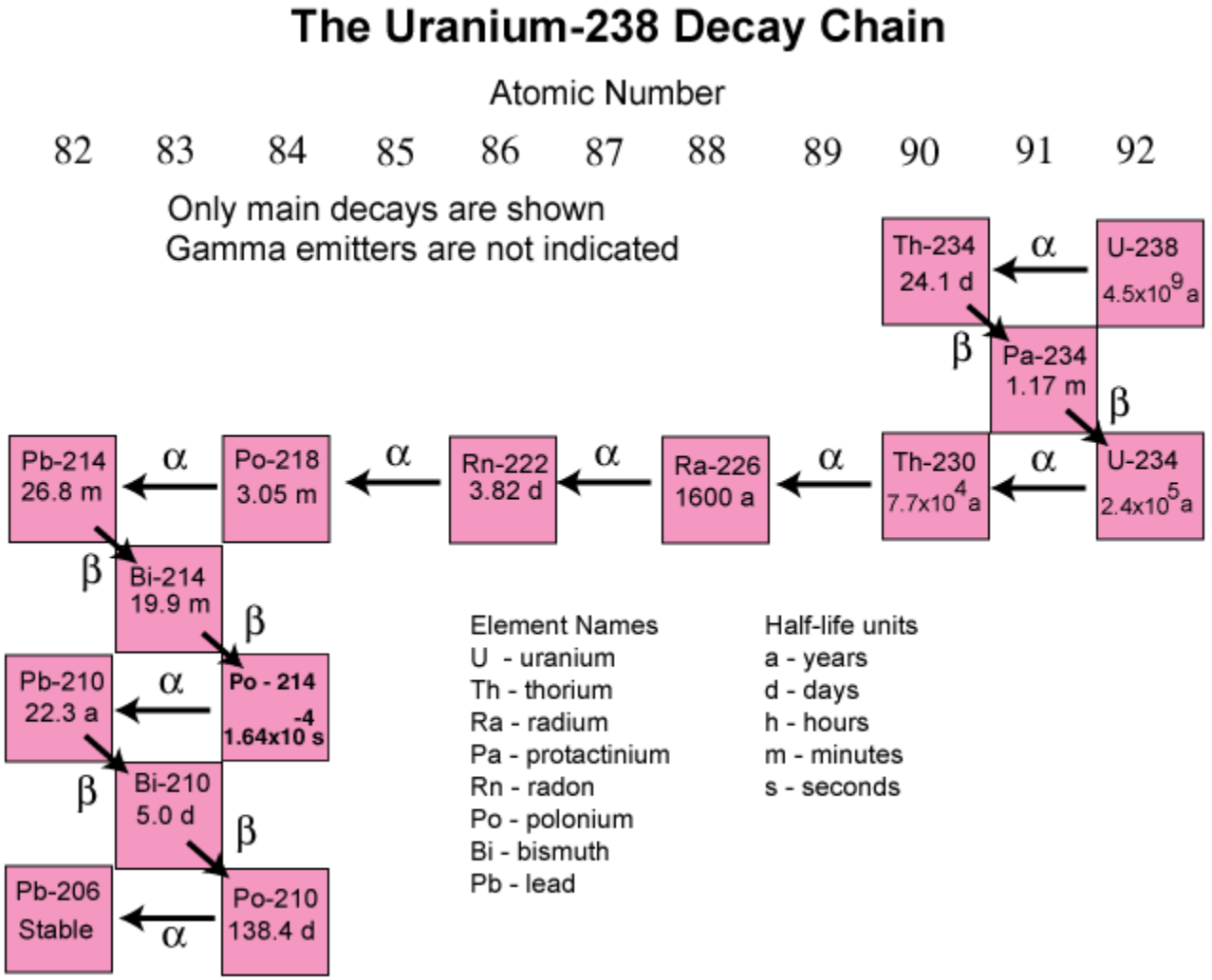
Fig. 2. Radon concentration data at the well in the southern part of Nishinomiya city, Hyogo prefecture, Japan.

1995, Kobe earthquake in Japan. KAMIOKANDE the underground cosmic ray observatory in central Japan. Detector : a semiconductor alpha particle detector (PIN photodiode).

Environmental conditions: The temp in the ground water is very stable, negligible pressure change and no rain fall.

Ref . Ground-Water Radon Anomaly Before the Kobe Earthquake in Japan
G Igarashi, S Saeki, N Takahata, K Sumikawa, S Tasaka, Y Sasaki, M Takahashi, Y Sano
Science 1995 Jul 7 Vol 269(5220):60-61 doi: 10.1126/science.269.5220.60

The U decay chain – what do we detect?



Thorium232 generates a similar serie, producing 220Rn (thoron) with a half life of 56 s

Changes in radon emission due to stress

Radon is a gas and it can escape from the surface of rocks.
Radon is soluble in water and can be transported by water.
The radon concentration in ground water is dependent the effective grain size in a rock - inversely proportional to the effective grain size in a rock.
In an earthquake due to stress microcracks are formed in the rocks.
Formation of the microcracks will reduce the effective grain size of rocks and therefore enhance radon concentration in the ground water.

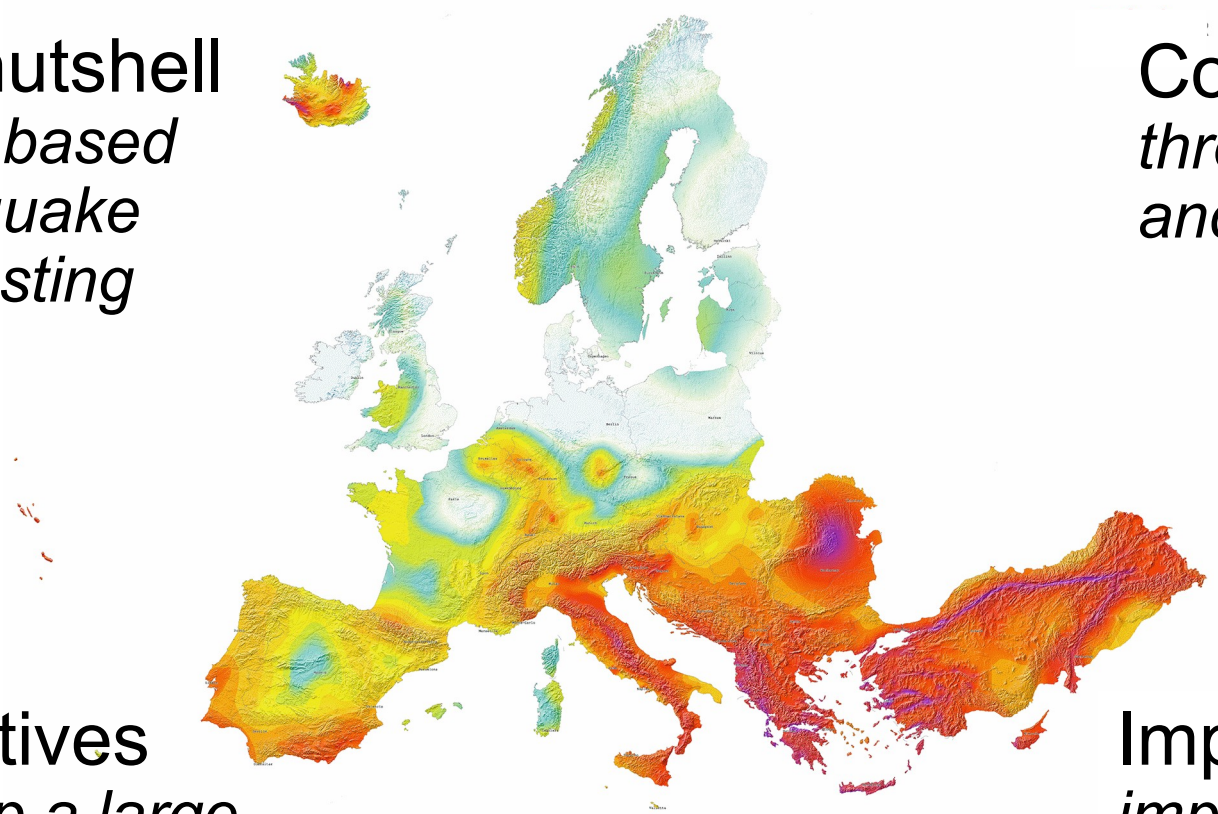
Decrease of radon – possible effects are changes in plates movements – from micro cracks to macro movements – sealing effects- depletion

artEmis

Awareness and resilience through European multi sensor system

In a nutshell

radon based earthquake forecasting



https://doi.org/10.12686/a15

Context

threat to our lifes and livelihood

Objectives

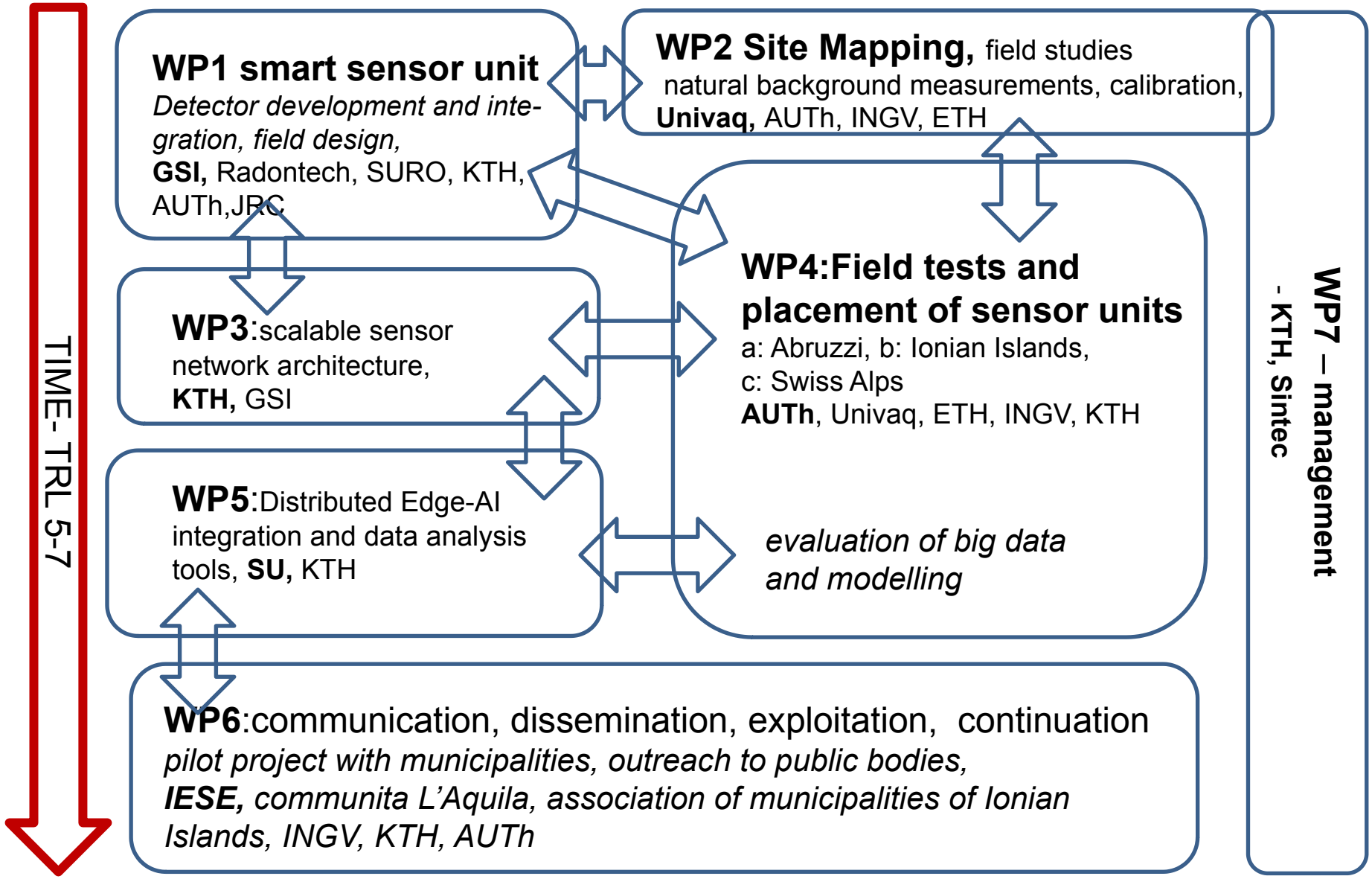
develop a large sensor radon network

Impact

improved earth-quake fore-casting methods

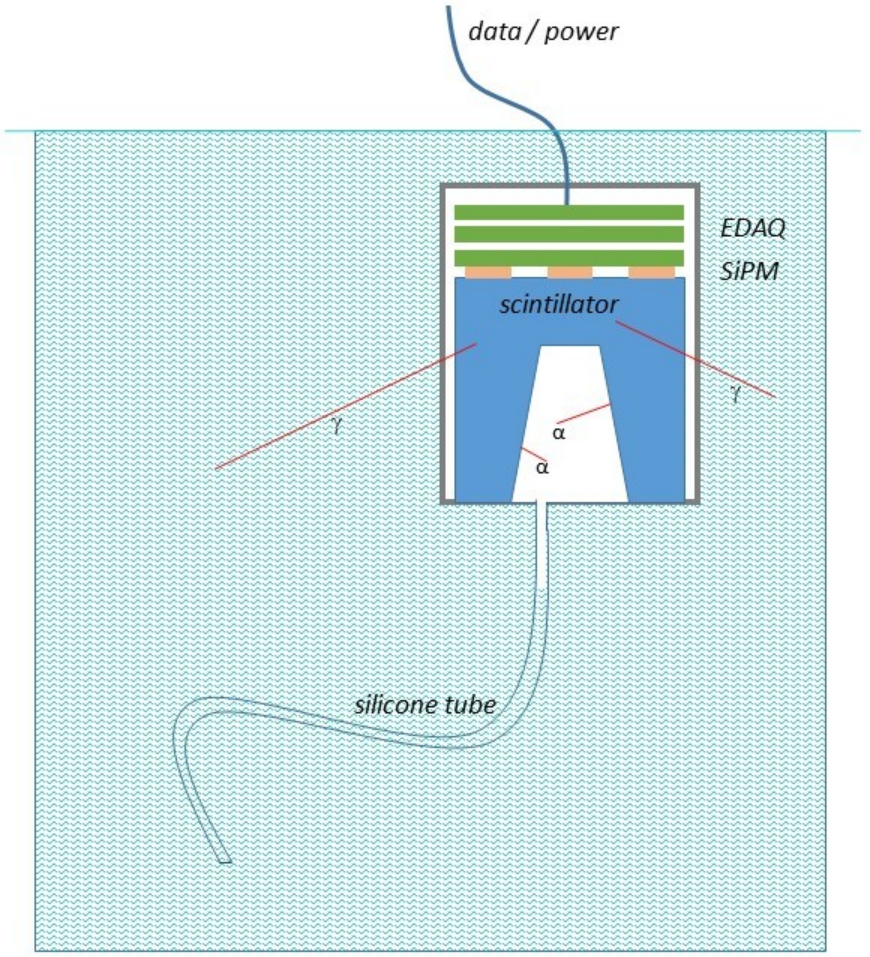
ArtEmis - Work Packages

awareness and resilience through European multi sensor system



ArtEmis – WP1 Sensor Unit

awareness and resilience through European multi sensor system



Calibration at SURO, Prag and in water tests at JRC European Joint Reseach Center, Geel.

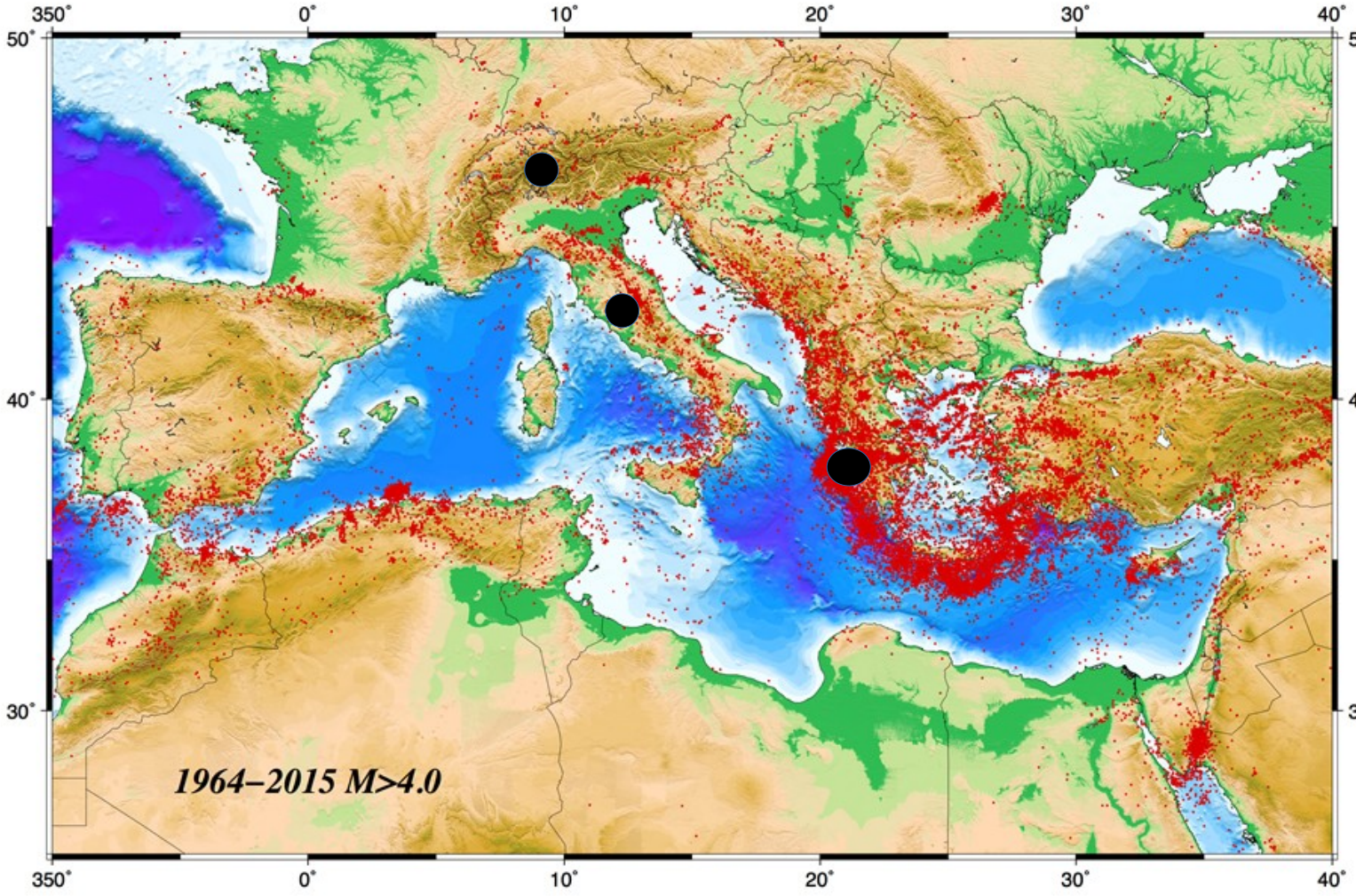
Detection of the characteristic γ and/or α radiation following the decay of radon (Rn) in water.

The core of the sensor device will be a scintillation detector, e.g. a CsI(Tl) crystal.The scintillation light will be read out by a set of silicon photomultipliers (SiPMs). Osmotic processes allow to extract dissolved Rn gas in water through silicone tubes.

Other parameters like temperature, acidity and hydrologic head (pressure) should be measurable with the same sensor device.

Geant simulations indicate that the planned CsI detector will detect about 10^4 events for an activity of 1Bq/l and one hour of sampling time.

ArtEmis – WP2 and WP4 Site Selection and Measurements - Covering fault lines in Greece, Italy and Switzerland



Courtasy of : Papadimitriou Eleftheria and Karakostas Vassilis, ARISTOTELIO PANEPISTIMIO THESSALONIKIS (AUTh)

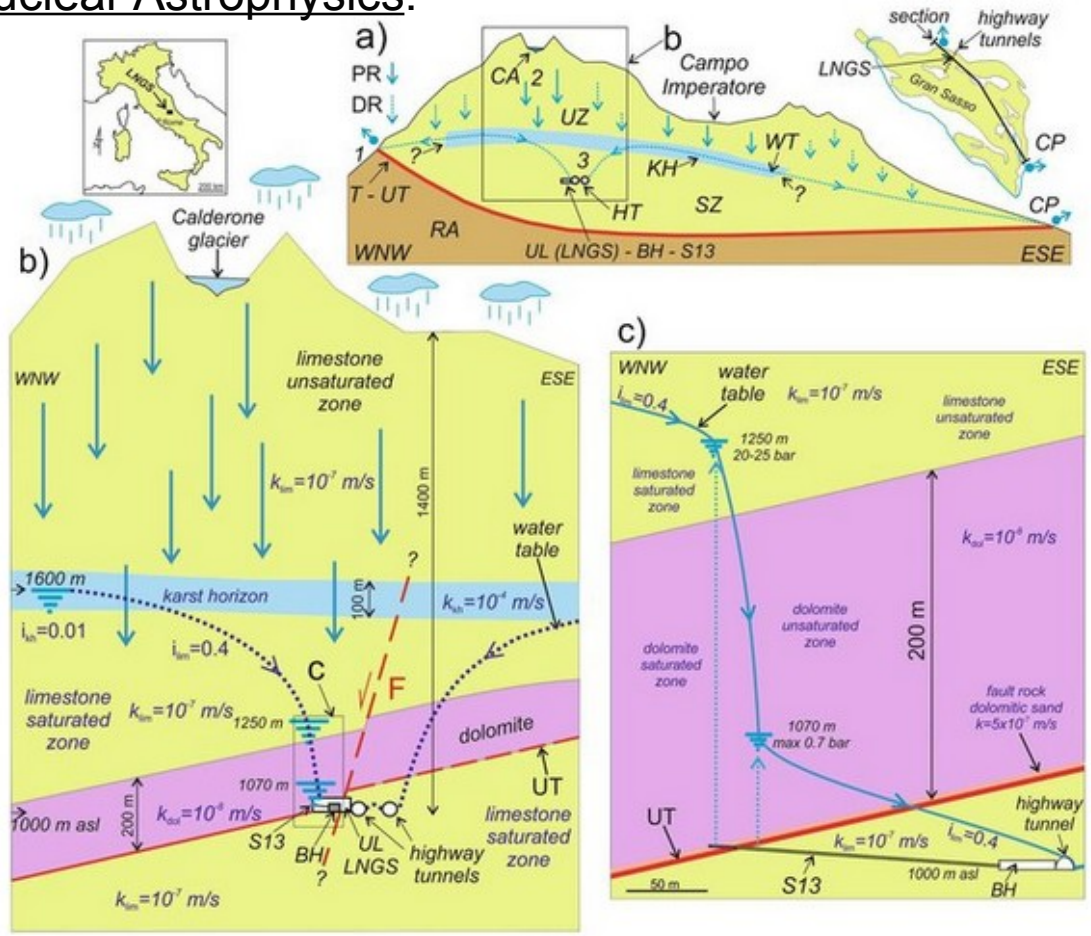
Abruzzi region (Gran Sasso, Fucino and Sulmona)

Ionian Islands specially Kefalonia and Lefkada Islands. Gulf of Corinth.

Swiss Alps Valais, Bedretto Laboratory

Bedretto Laboratory, ETH Zurich a unique research infrastructure run by ETH Zurich and gives ideal conditions to study the dissolved gases and chemical composition of rock fluids. It is located in the Swiss Alps 1.5 kilometres below the surface and in the middle of a 5.2 kilometres long tunnel connecting the Ticino with the Furka railway tunnel. The lab performs controlled and repeatable earthquakes of magnitude 1 or 2.

Laboratori Nazionali del Gran Sasso (LNGS) is the largest underground research center in the world. Neutrino Physics, search for neutrino mass in neutrinoless double beta decays, search for Dark Matter, and Nuclear Astrophysics.



Figure

Caption

Figure 2. (a) Scheme (not in scale) of the Gran Sasso aquifer transversal to the highway tunnels and passing through the underground laboratories of Gran Sasso (LNGS), borehole hall and S13 area 77. UZ: Unsaturated Zone; SZ: Saturated Zone; KH: Karst Horizon; RA: Regional Aquiclude; T: permeability boundary (regional Thrust); UT: local thrust named Up … Read more

This figure was uploaded by De Luca Gaetano

https://www.researchgate.net/publication/316557307_Hydraulic_pressure_variations_of_groundwater_in_the_gran_sasso_underground_laboratory_during_the_amatrice_earthquake_of_August_24_2016/figures?lo=1

Laboratori Nazionali del Gran Sasso (LNGS)

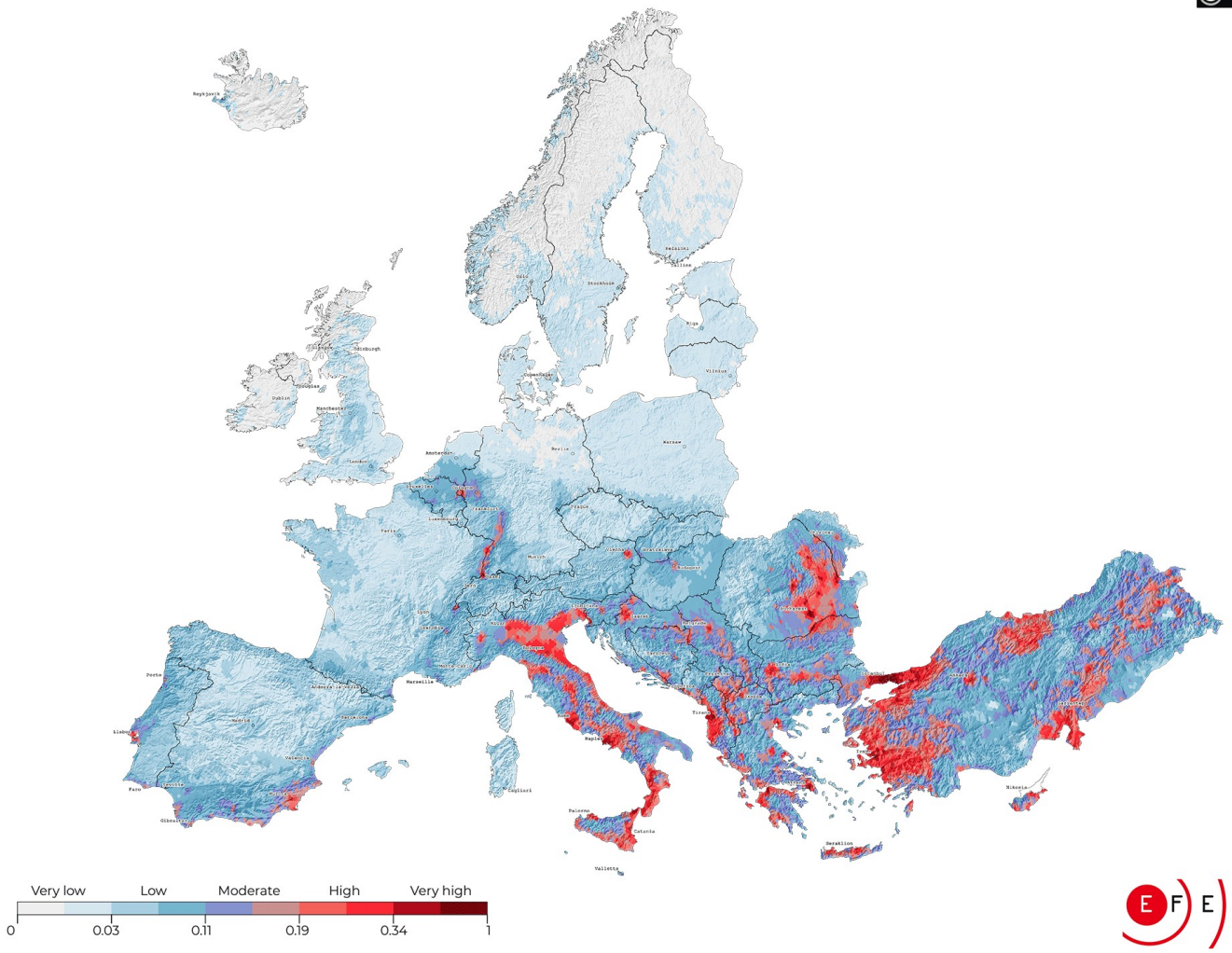
Borehole S13

City of L’Aquila, The main shock occurred at 03:32 CEST (01:32 UTC) on 6 April 2009, and was rated 5.8 or 5.9 on the Richter magnitude scale and 6.3

Ten years after the quake, Italy's ravaged heart is still struggling to recover, https://www.theguardian.com/world/2019/apr/07/george-clooney-laquila-italy-earthquake-restoration

Ionian Islands : Zakynthos, Ithaca, Corfu, Kefalonia, Lefkada, Paxi (or Paxos) and Kythira are the seven largest and most popular islands of the group

Impressions from the first Kick-off meeting? Future wishes and vision for artEmis?



Citation for the risk map:
Crowley H., Dabbeek J., Despotaki V., Rodrigues D., Martins L., Silva V., Romão X., Pereira N., Weatherill G., Danciu L. (2021). European Seismic Risk Model (ESRM20), EFEHR Technical Report 002, V1.0.0, 84 pp, https://doi.org/10.7414/EUC-EFEHR-TR002-ESRM20

ArtEmis Family!

The network architecture described in WP3 follows state of the art of implementation of wireless
connection, making use of existing 3G and 4G networks.

WP5 will warrant suitable format of
the data stream and storage. The aim of this WP5 is to build a generative deep learning statistical model able
to integrate heterogeneous data in order to predict significant seismic events, both spatially and timewise.

Changes in radon emission in response to stress

Radon can only escape from the surface of rock material – penetration length in air ~4cm
radon concentration in ground water proportional to grain size of bed rock
stress can change the grain size and result in **increased** radon emission
decrease of radon – possible effects are changes in plates movements – from micro cracks to macro movements – sealing effects- depletion

Absorbing materials and their alpha particle penetration depths.

Absorber	**Density**	**Alpha Range**	**Comments**
air (STP)	1.2 mg/cm^3	3.7 cm	-
paper (20lb)	0.89 g/cm^3	53 μm	one sheet = 89 μm
water (soft tissue)	1.0 g/cm^3	45 μm	will not penetrate skin

Courtasy of R. Wyss

In a nutshell…

ArtEmis will design, build, and operate a smart and scalable multi sensor system comprising of about 100-200 novel low-cost geochemical sensors, that will measure with unprecedent spatial and temporal resolution changes in radon concentration in ground water, together with other observables like temperature and acidity.

Advance knowledge on the processes that drive geo chemical changes in deep layers of the earth in response to increased tension and stress. We expect artEmis to clarify the longstanding issue of earthquake predictions by means of geochemical precursors like changes in radon concentration.

Context

- Earthquakes constitutes one of the most damaging natural hazards on Earth. Increased Radon gas emission from deep layers has been one of the most promising precursors. However, measurements in soil or air are hampered with large uncertainties. Direct measurements in water are more reliable but more difficult. Hence, this project embarks on a new approach to advance earthquake forecasting:
- Novel sensor design for in water measurements
- Covering fault lines in Greece, Italy and Switzerland
- AI supported analysis

Objectives

The development of a radiation sensor optimizing prize versus performance for measurements in ground water in real time.

The integration of the radiation sensor with other sensors into a single smart design reducing maintenance and energy consumption.

The deployment of a sufficient large number of sensors that will generate geographical dense coverage and thus allow for correlating observed seismicity and radon concentration.

The use of machine learning – deep learning algorithms for the analysis of the data that will yield new insights into how to best analyse observed radon time-series and seismicity.

The collaboration with municipalities to develop models for widespread deployment, public engagement, and scientific outreach.

The system is designed for scalability.

In a nutshell…

ArtEmis will develop a smart sensor system, monitoring radon, temperature, acidity and other observables in groundwater in real time. The project aims to produce 100-200 sensors, that will be deployed in sensitive sites in collaboration with municipalities. Changes in radon concentration have the potential to serve as precursor for earthquakes. To advance our knowledge in this field we propose the development of a cheap sensor system, that can be employed on a large scale in earthquake prone areas of Europe. The real time collected data is used to build machine learning (ML) models for the analysis. The collected and AI processed data will generate a real time map of hydrological and geochemical changes that is shared to the scientific community and public bodies engaged in the project.

We expect artEmis to clarify the longstanding issue of earthquake predictions by means of geochemical precursors like changes in radon concentration.

Impact

Advance knowledge on the processes that drive geo chemical changes in deep layers of the earth in response to increased tension and stress.
We expect artEmis to clarify the longstanding issue of earthquake predictions by means of geochemical precursors like changes in radon concentration.
artEmis will set a new standard for monitoring at the European level. A distributed system as envisioned by artEmis can be considered as a blueprint of European efforts for awareness and risk assessment, that is shared to public and individual citizens alike. Such a system will strengthen the trust in the society via open data sharing.

In a nutshell…

ArtEmis will develop a smart sensor system, monitoring radon, temperature, acidity and other observables in groundwater in real time. The ground-breaking sensor design will assure affordability, resilience and low power consumption optimizing life cycle management. The project aims to produce 100-200 sensors, that will be deployed in sensitive sites in collaboration with municipalities. Changes in radon concentration have the potential to serve as precursor for earthquakes and volcano eruptions. To advance our knowledge in this field we propose the development of a cheap sensor system, that can be employed on a large scale in earthquake prone areas of Europe. The real time collected data is used to build machine learning (ML) models for the analysis. The collected and AI processed data will generate a real time map of hydrological and geochemical changes that is shared to the scientific community and public bodies engaged in the project. A pilot project engaging citizens of the participating municipalities is part of the dissemination and exploitation activities. We expect artEmis to clarify the longstanding issue of earthquake predictions by means of geochemical precursors like changes in radon concentration. The system is designed for scalability. Dissemination and exploitation activities are tailormade to ensure support and expansion of artEmis after the project's completion.

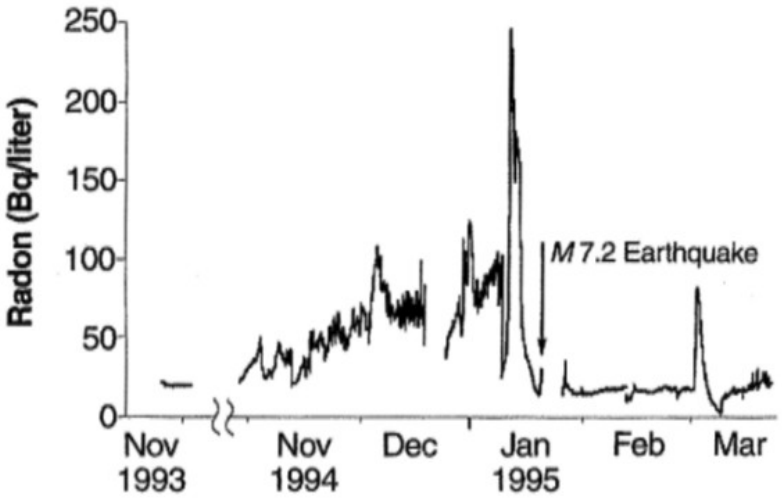


Fig. 2. Radon concentration data at the well in the southern part of Nishinomiya city, Hyogo prefecture, Japan.

Ground-Water Radon Anomaly Before the Kobe Earthquake in Japan

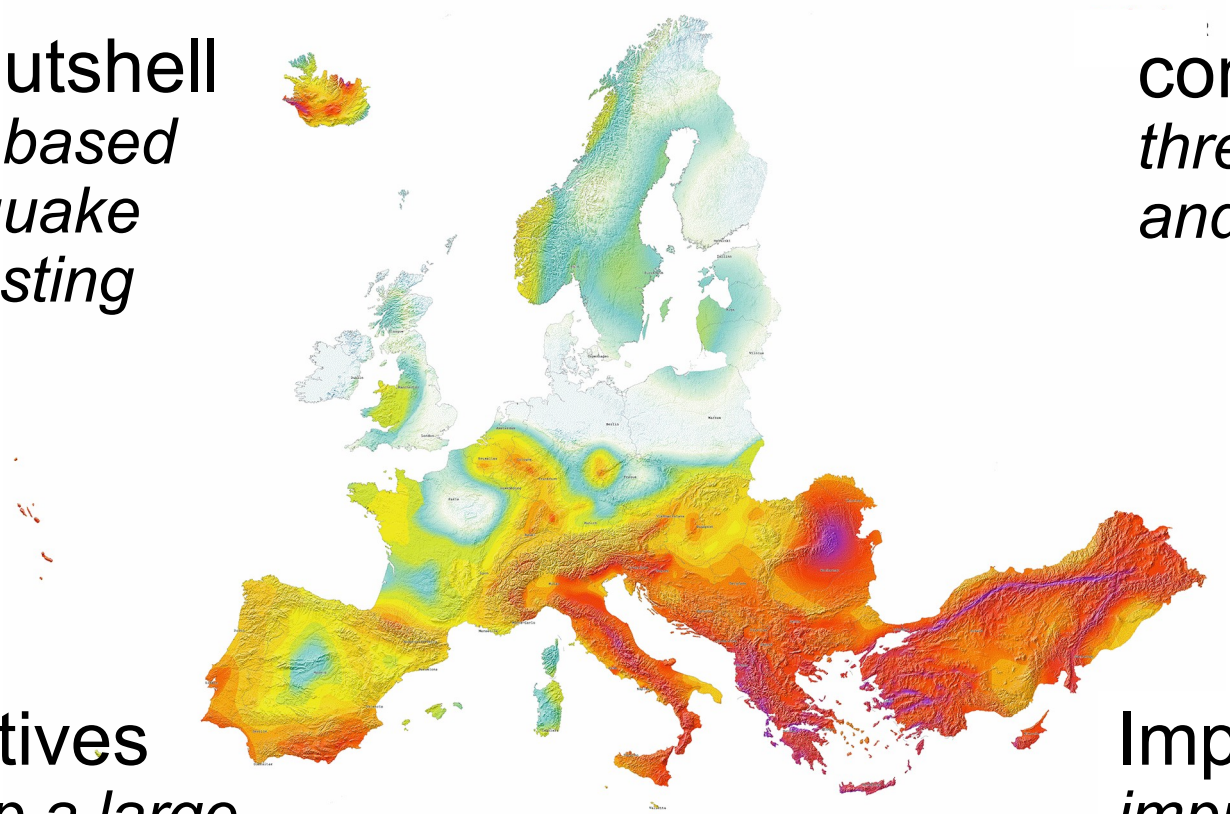
G.IgarashiS. SaekiN. TakahataK. SumikawaS. TasakaY. SasakiM. Takahashiand Y. Sano Authors Info & AffiliationsScience7 Jul 1995Vol 269, Issue 5220pp. 60-61
DOI: 10.1126/science.269.5220.60

artEmis

Awareness and resilience through European multi sensor system

in a nutshell

radon based earthquake forecasting



context

threat to our lifes and livelihood

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develop a large sensor radon network

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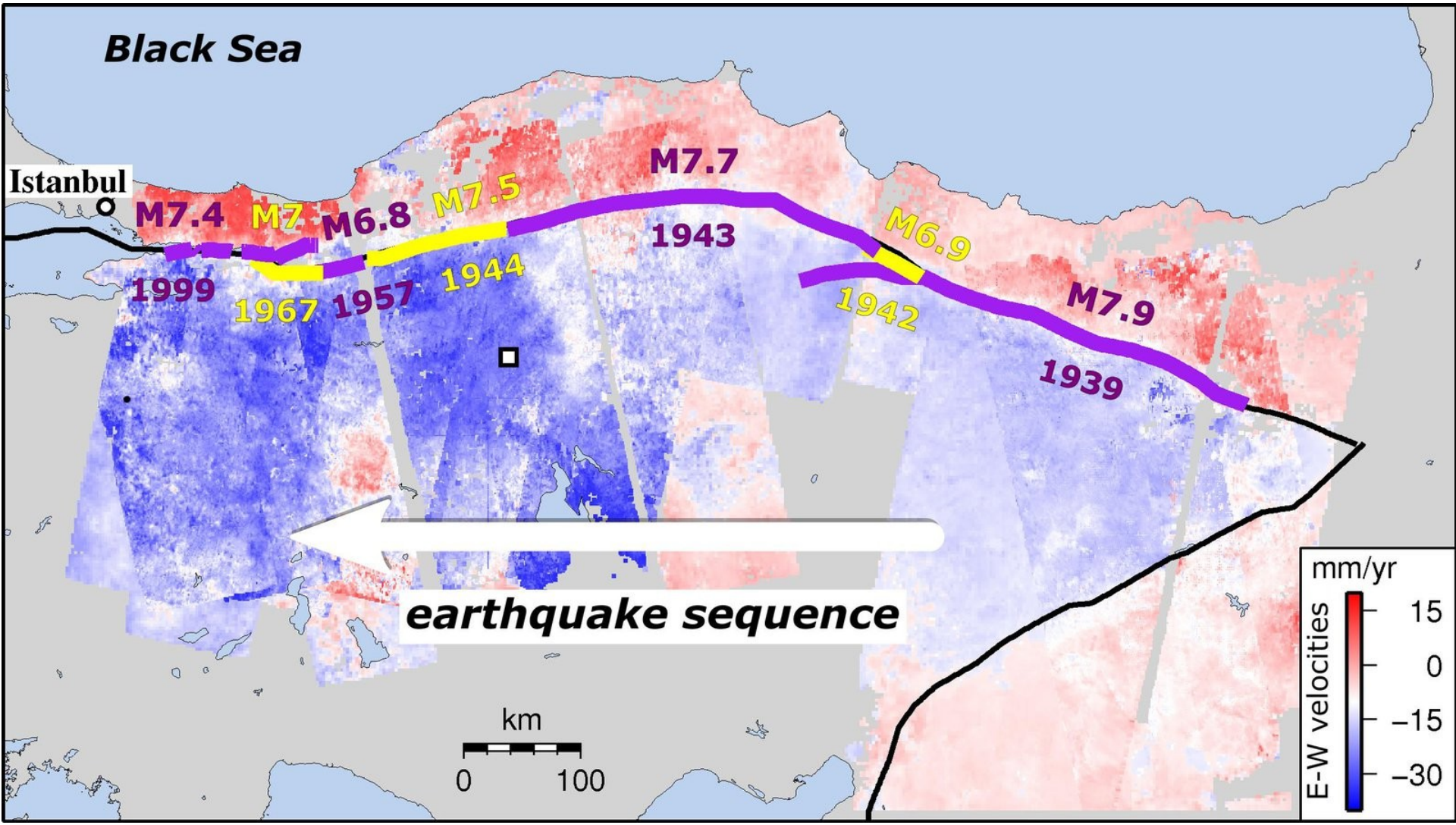
improved earth-quake fore-casting methods

Citation for the hazard map:
Danciu L., Nandan S., Reyes C., Basili R., Weatherill G., Beauval C., Rovida A., Vilanova S., Sesetyan K., Bard P-Y., Cotton F., Wiemer S., Giardini D. (2021). The 2020 update of the European Seismic Hazard Model: Model Overview. EFEHR Technical Report 001, v1.0.0, https://doi.org/10.12686/a15



https://www.jpl.nasa.gov/images/pia22412-turkish-fault-reveals-seismic-steadiness

Credit ESA/NASA/JPL-Caltech/University of Leeds (U.K.)

ARTEMIS: EARTHQUAKE FORECASTING USING RADON DETECTORS

Ayse Nyberg[1], Ramon Wyss[1], Torbjörn Bäck[1], + the Artemis EU collaboration

[1]Physics Department, KTH, Stockholm.

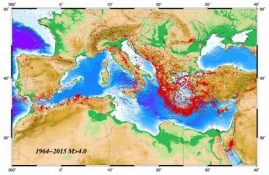
Objective

Earthquakes are one of the most damaging natural hazards on Earth. This project embarks on a new approach to advance earthquake forecasting.

Where will we measure?

ArtEmis will choose three different regions for measurements according to seismic activity and geological property:

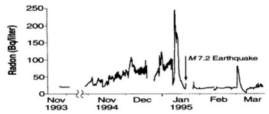
- The Ionian Islands in Greece
- The Abruzzi region in Italy
- Some sites in Switzerland.



Seismic activity in Europe. Each red dot corresponds to one earthquake with magnitude larger than 4.0

Radon transients in groundwater

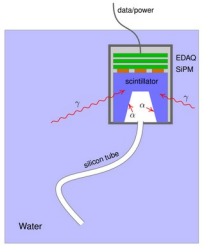
The stress in deep layers of the Earth crust creates micro cracks in rocks that enable radon to escape and to diffuse towards the surface. As groundwater travels through the crust, it collects information on tectonic processes that take place at several kilometres depth, inaccessible to direct observations.
In this project, we focus on a promising observable, changes in radon concentration in groundwater as potential sources of information on imminent earthquakes (see e.g. Igashi 1995, Riggio 2015, Morales-Simfors 2019).



Igarashi et al, Science 269, 60 (1995)

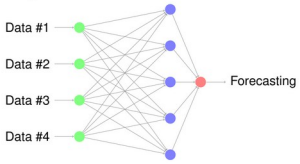
A new alpha/gamma radiation sensor

Artemis will develop a new scintillation detector for radon, integrated with other sensors, that is capable to directly measure in groundwater.



Smart Sensor Network and AI forecasting models

The sensor network design integrates features of AI-supported self-awareness, adaption and smart signalling.



Student Involvement

Within the framework of artEmis, we plan for:

- one PhD position based at GSI, Germany, but supervised from KTH.
- several MSc thesis projects
- several Bachelor projects,
- other student projects, e.g. in the sensor building phase.

Experiments at Bedretto

In Switzerland, the project group will have access to the Bedretto Laboratory which is a unique research infrastructure run by ETH Zurich where controlled and repeatable earthquakes of magnitude 1 or 2 are performed.

Project Outlook

ArtEmis is a cross-disciplinary systemic project integrating three new developments in science:

1. In-situ radon measurements
2. Massive sensor system to provide improved statistics
3. Machine learning for advanced analysis

A successful project will enable larger role out in Europe and world-wide.

Contact information:

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Ramon Wyss: wyss@kth.se
Torbjörn Bäck: back@kth.se

References:
G. Igarashi. et al. Groundwater radon anomaly before the Kobe earthquake in Japan. Science, 269, 60 (1995)
A. Riggio and M. Santulin, Earthquake forecasting: a review of radon as seismic precursor, Bollettino di Geof. Teorica ed Appl. Vol. 56, n. 2, pp. 95-114; June 2015
Nury Morales-Simfors, Ramon A. Wyss & Jochen Bundschuh, Recent progress in radon-based monitoring as seismic and volcanic precursor: A critical review; Critical Reviews in Environmental Science and Technology, (2019) ; DOI: 10.1080/10643389.2019.1642833

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