Underground site characterization for Einstein Telescope

Wolfango Plastino

Department of Mathematics and Physics - Roma Tre University

Section of Roma Tre - National Institute of Nuclear Physics

wolfango.plastino@uniroma3.it

Content

Environmental noises

a) seismic

b) atmospheric

c) infracoustic

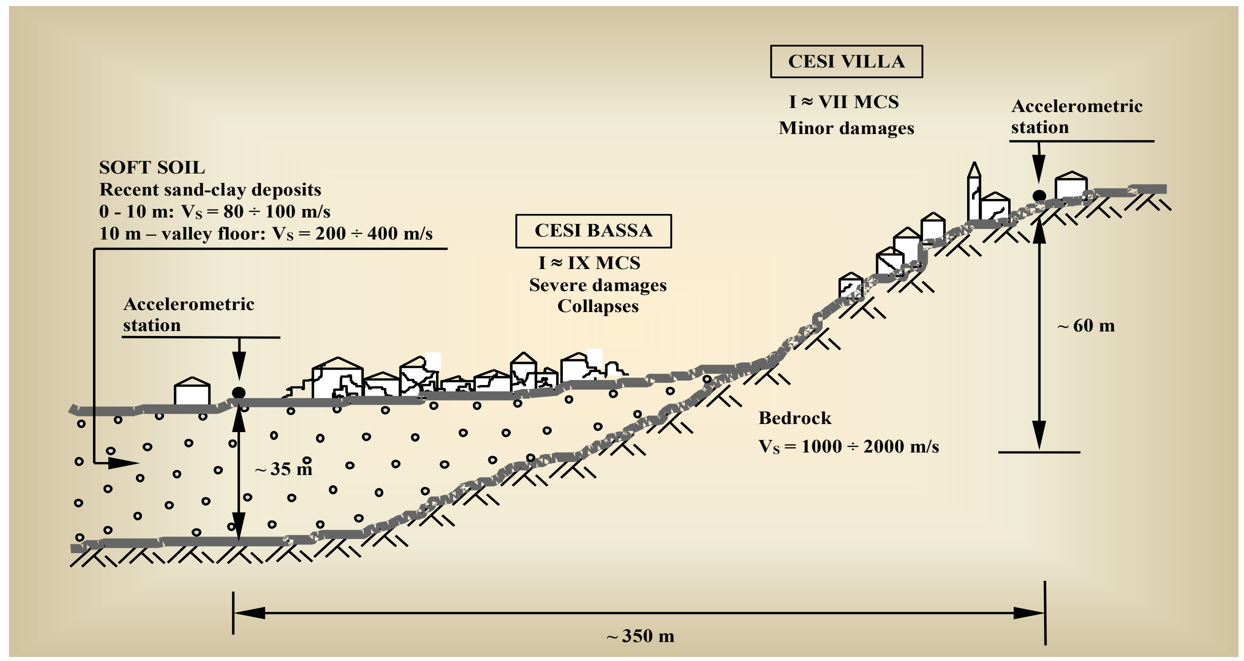
d) thermoeleastic

e) poroelastic

f) electromagnetic

g) radioactivity

a)



Cesi (MC) (1997 M_W=6.0) - effect of small scale litho-stratigraphic variations

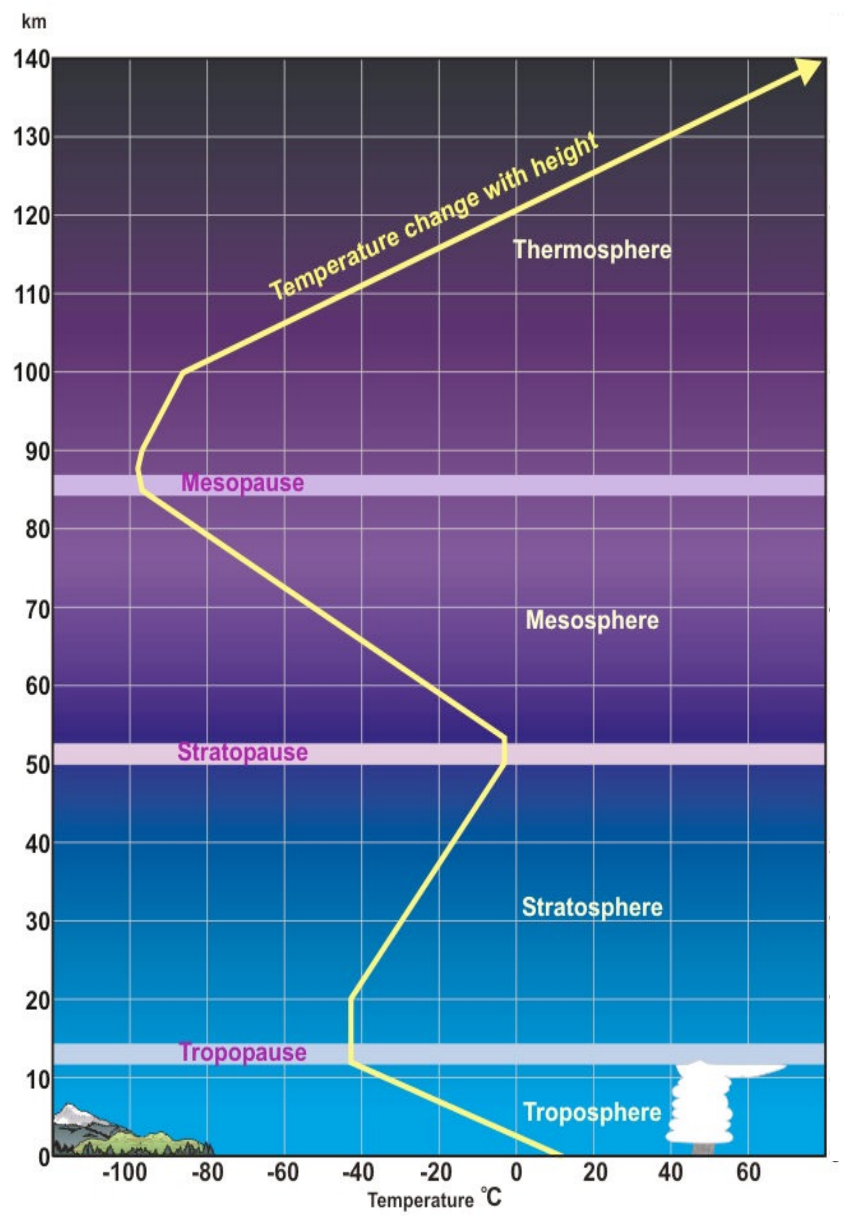
'skin' effect concerns the spectral amplitudes of surface waves in layered media. A possible interpretation is that the presence of a sharp variation in the V_S profile induces energy-trapping phenomena between the surface (where the noise originates) and the impedance contrast at depth, which result in high-pass filtering of the surface wavefield. In fact, since the penetration depth of surface waves depends on the frequency energy trapping in the shallowest part of the subsoil due to the presence of a sharp impedance contrast at the basis of soft sediments is expected to affect the surface wave spectrum by transferring energy from low-frequency (more depth-penetrating) to high-frequency (less depth-penetrating) components. The frequency boundary between the enhanced and damped spectral components is expected to correspond to the resonance frequency of the soft sedimentary layer that identifies the range of frequency involved in the energy-trapping process. Instead, the amount of the energy transfer is a function of the sharpness of the impedance contrast at the bottom of the low-velocity layer.

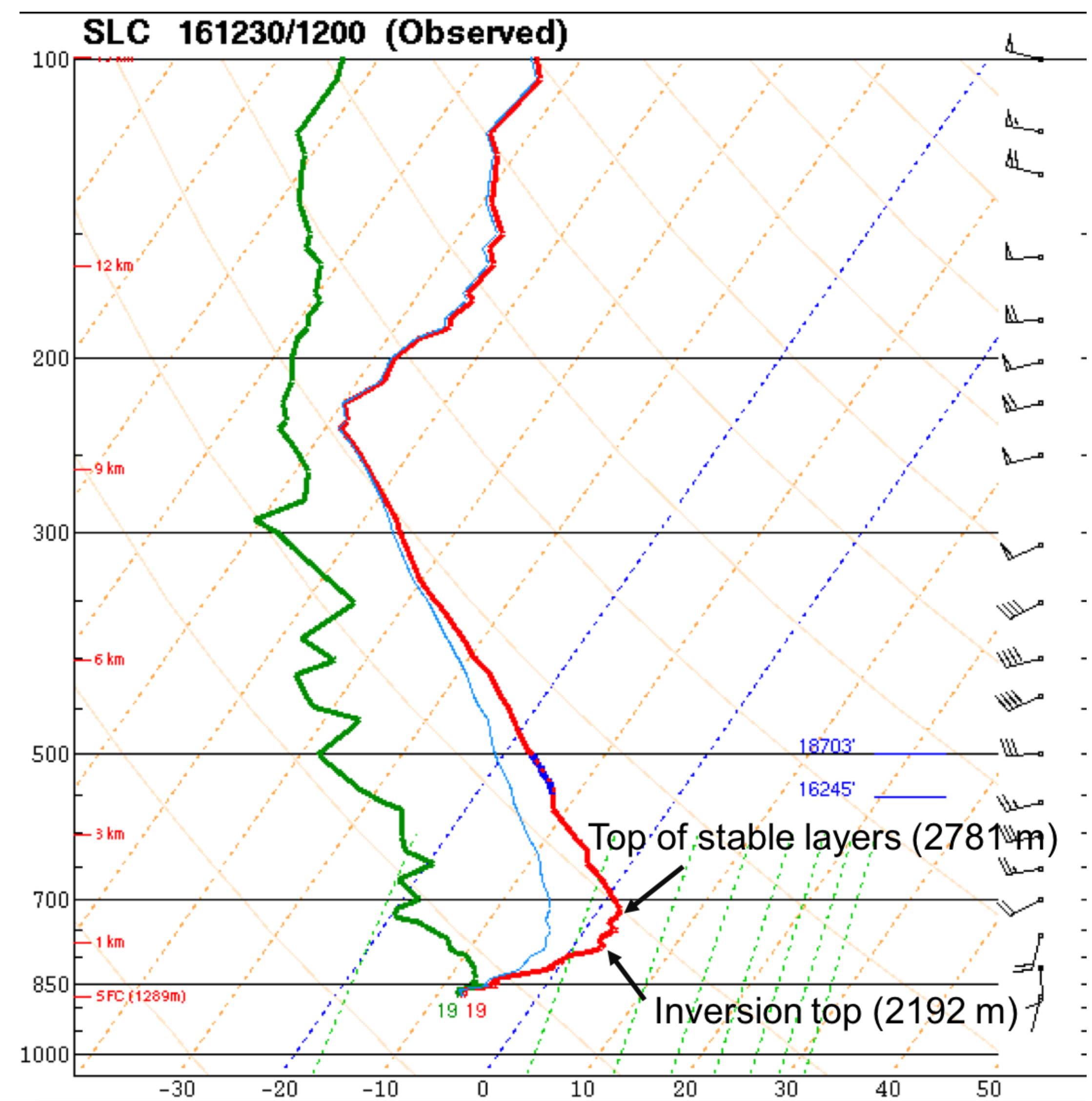
a)

The observed phenomena are the effect of the constructive **interference** (resonance) of seismic waves (mainly S phases) trapped within **geological bodies** bounded by **large seismic impedance contrasts** (soft soil/bedrock, soil/free surface, etc.) **irrespective** to the absolute impedance values

Seismic impedance *relative to any seismic phase is the product of the propagation velocity and bulk density*

Ambient vibrations (anthropic sources, meteoclimatic conditions, sea waves) exhibit an inherent stochastic nature showing large amplitude variations b)


km
Temperature change with height
Thermosphere
Mesopause
Mesosphere
Stratopause
Stratosphere
Tropopause
Troposphere
Temperature °C


SLC 161230/1200 (Observed)
Top of stable layers (2781 m)
Inversion top (2192 m)
18703'
16245'
SFC (1289m)

b)

A **ground inversion** develops when air is cooled by contact with a colder surface until it becomes cooler than the overlying atmosphere; this occurs most often on clear nights, when the ground cools off rapidly by radiation. If the temperature of surface air drops below its dew point, fog may result. Topography greatly affects the magnitude of ground inversions. If the land is rolling or hilly, the cold air formed on the higher land surfaces tends to drain into the hollows, producing a larger and thicker inversion above low ground and little or none above higher elevations.

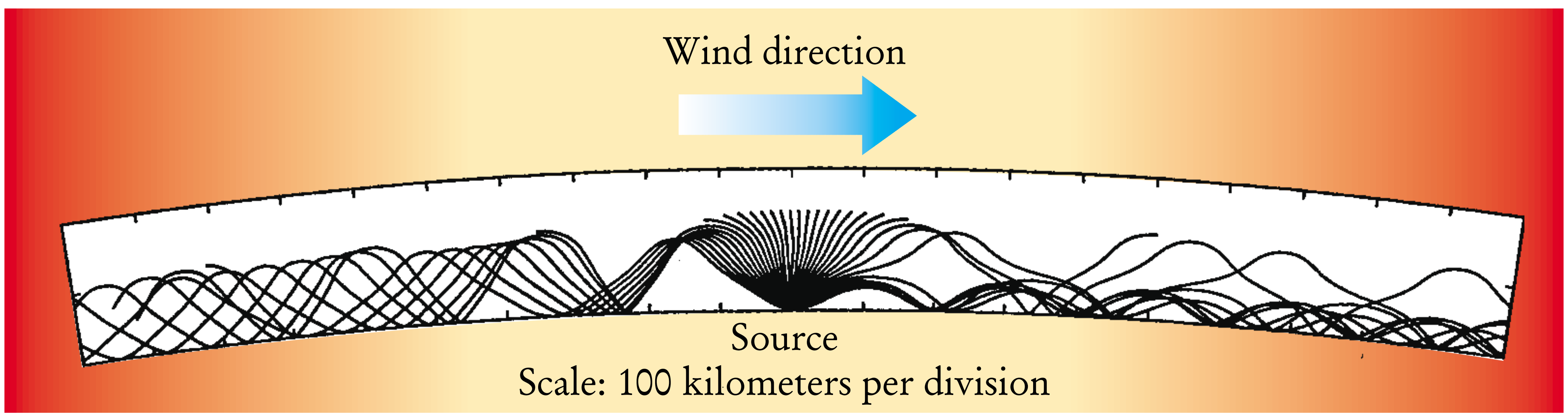
A **turbulence inversion** often forms when quiescent air overlies turbulent air. Within the turbulent layer, vertical mixing carries heat downward and cools the upper part of the layer. The unmixed air above is not cooled and eventually is warmer than the air below; an inversion then exists.

A **subsidence inversion** develops when a widespread layer of air descends. The layer is compressed and heated by the resulting increase in atmospheric pressure, and as a result the lapse rate of temperature is reduced. If the air mass sinks low enough, the air at higher altitudes becomes warmer than at lower altitudes, producing a temperature inversion. Subsidence inversions are common over the northern continents in winter and over the subtropical oceans; these regions generally have subsiding air because they are located under large high-pressure centres.

A **frontal inversion** occurs when a cold air mass undercuts a warm air mass and lifts it aloft; the front between the two air masses then has warm air above and cold air below. This kind of inversion has considerable slope, whereas other inversions are nearly horizontal. In addition, humidity may be high, and clouds may be present immediately above it.

c)

Infrasonic waves can propagate thousands of kilometers due to low atmospheric absorption at low frequencies. Natural sources are severe weather, volcanoes, bolides, earthquakes, surf, mountain waves, open ocean wave-wave interactions. Man-made infrasound is associated with vehicles and aircraft, machinery, and the interactions of weather on buildings and other structures.



Computer ray trace models how infrasound at a frequency of 1 Hz is refracted and channeled over long distances by the temperature and wind structure of the atmosphere. A 60 m/s jet of wind blowing to the right at 60 km altitude is simulated to show the difference between upstream and downstream propagation. Rays that end abruptly are absorbed by atmospheric viscosity and thermal conduction.

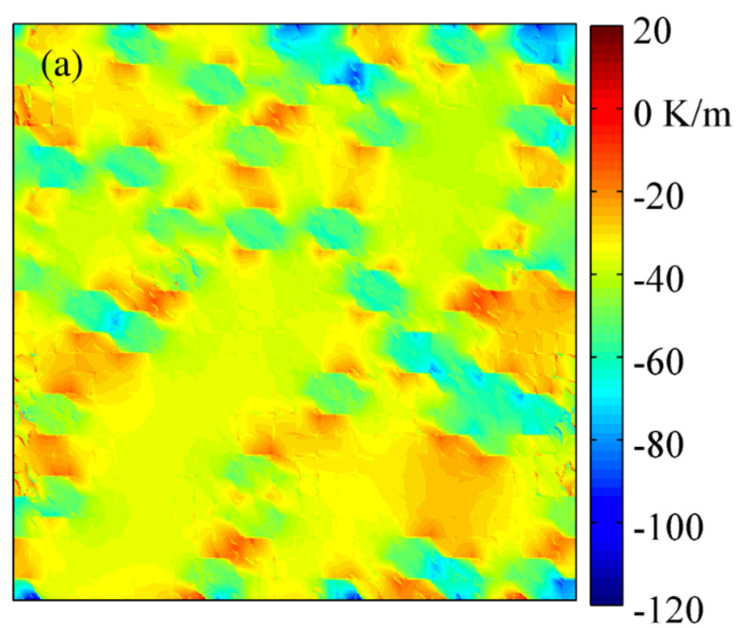
c)

Infrasonic resonances in underground cavities have been detected due to the tunnel geometries are simple enough for direct application of the Helmholtz resonator theory. Spectral analysis indicates that subacoustic resonance is responsible for numerous reports of periodically fluctuating or reversing tunnel winds.

d)

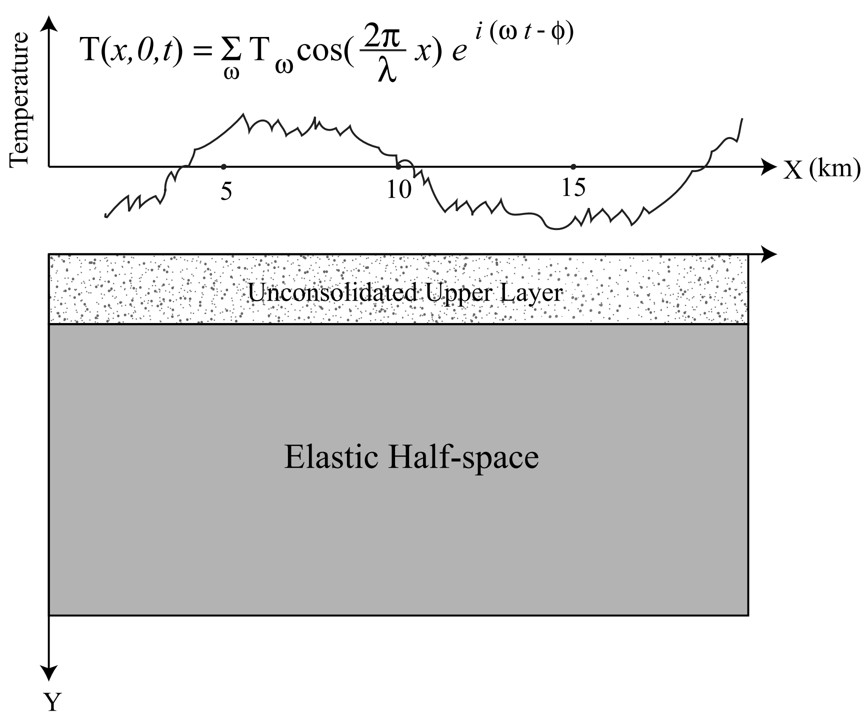
Thermoelastic damping, which arises when a material is subjected to cyclic stress by heating and cooling. Thus, due to the resulting heat flux, energy is lost to bring about this damping.
The magnitude of the energy loss depends on the vibrational frequency and the structure's thermal relaxation time constant, which is the effective time that the material requires to relax after an applied constant stress or strain. Therefore, the effect of thermoelastic dissipation, and consequently the damping, is most pronounced when the vibration frequency is close to the thermal relaxation frequency.

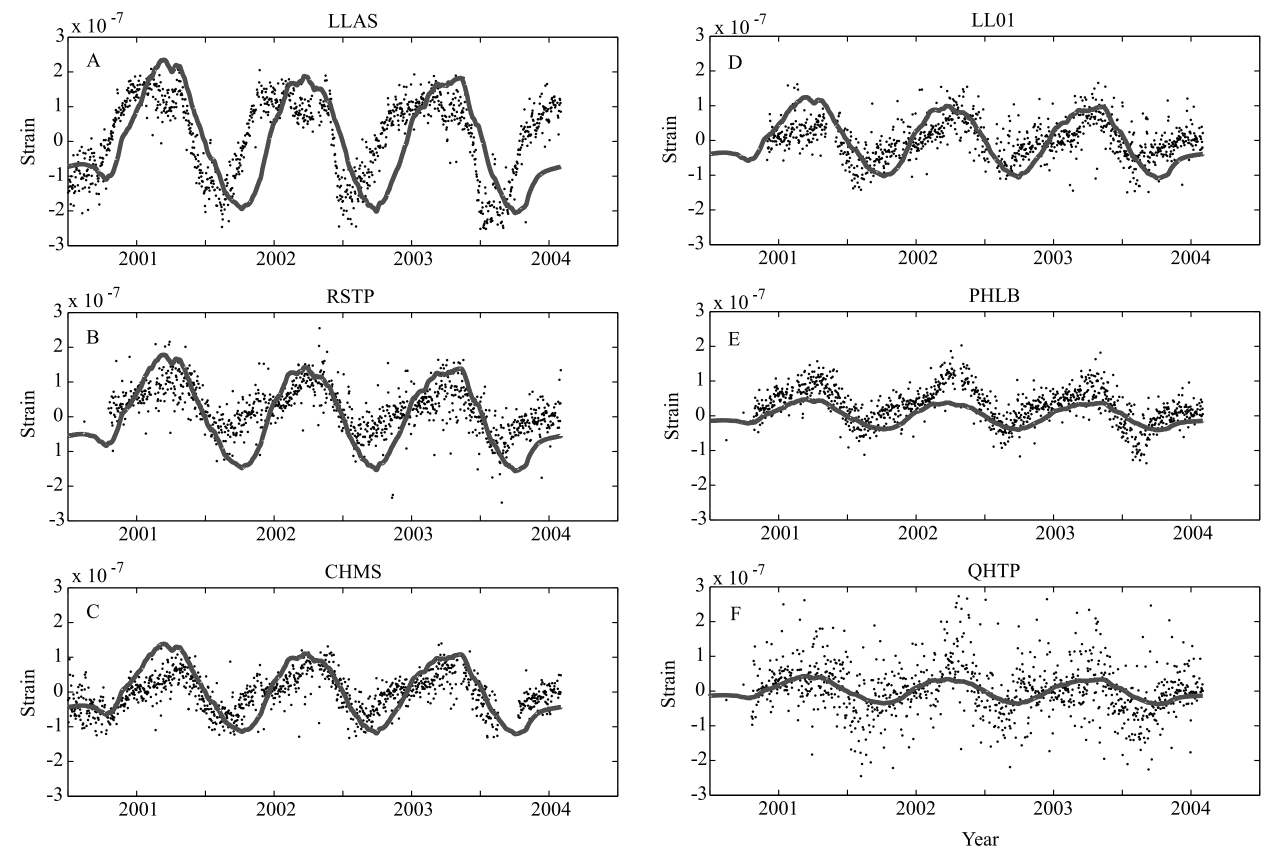
If the porous media is heterogenous on a scale larger than that of the porosity, there can be stress-induced flow of fluid between regions in the material, analogous to the intercrystalline thermal currents associated with thermoelastic coupling.



snapshot of the temperature gradient within a standard microstructure at the time of peak tension. The microstructure has a domain of 5 mm and grain diameter of 360 µm

d)



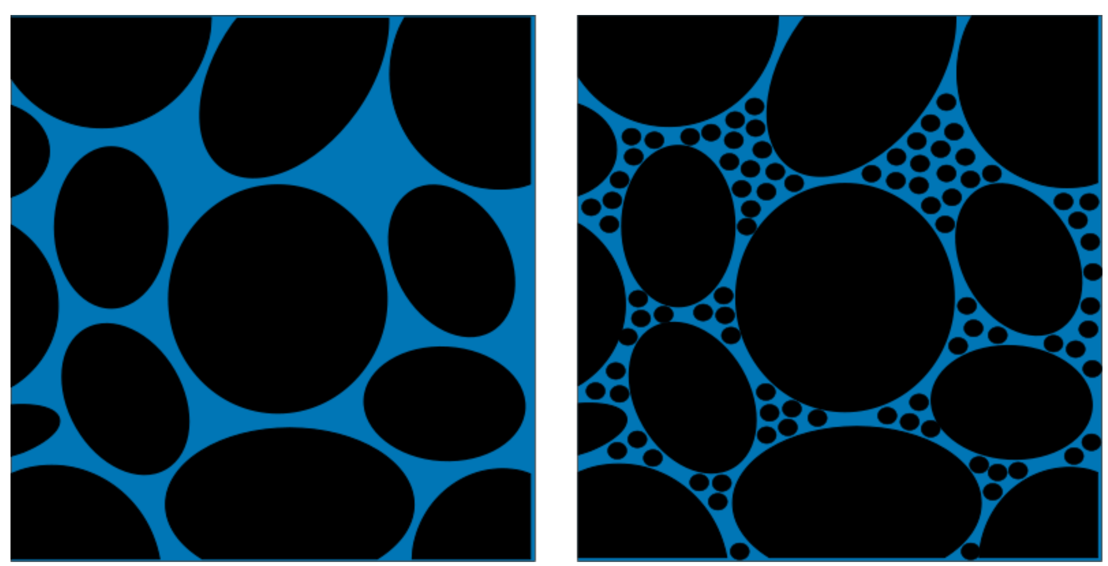


The predicted thermoelastic strain from the observed local atmospheric temperature record assuming an elastically decoupled layer over a uniform elastic half-space and compare the seasonal variations in thermoelastic strain to the horizontal GPS position time series. The temperature time series is used to compute thermoelastic strain at each station on the basis of its relative location in the temperature field, and assuming a wavelength for the temperature field that is related to the local topography. The depth of the decoupled layer is inferred from the phase delay between the temperature record and the GPS time series.

© doi:10.1029/2005JB003716

e)

Darcy's law allows us to obtain the flux directly from the pressure gradient. Variable permeability caused by differing amounts of fluid passing through the pores implies the presence of 'memory' in the matrix or in the fluid. In practice, this variation in permeability may occur in geothermal areas where crystals formed during expansion of the fluid obstruct the path of incoming fluid, chemical reaction of the fluid with the matrix may modify the pores. It is clear that in these cases the variation in permeability depends on the amount of fluid passed through the matrix, which implies a system 'memory'.



e)

Long-term strains (June.- Sep. 2017)

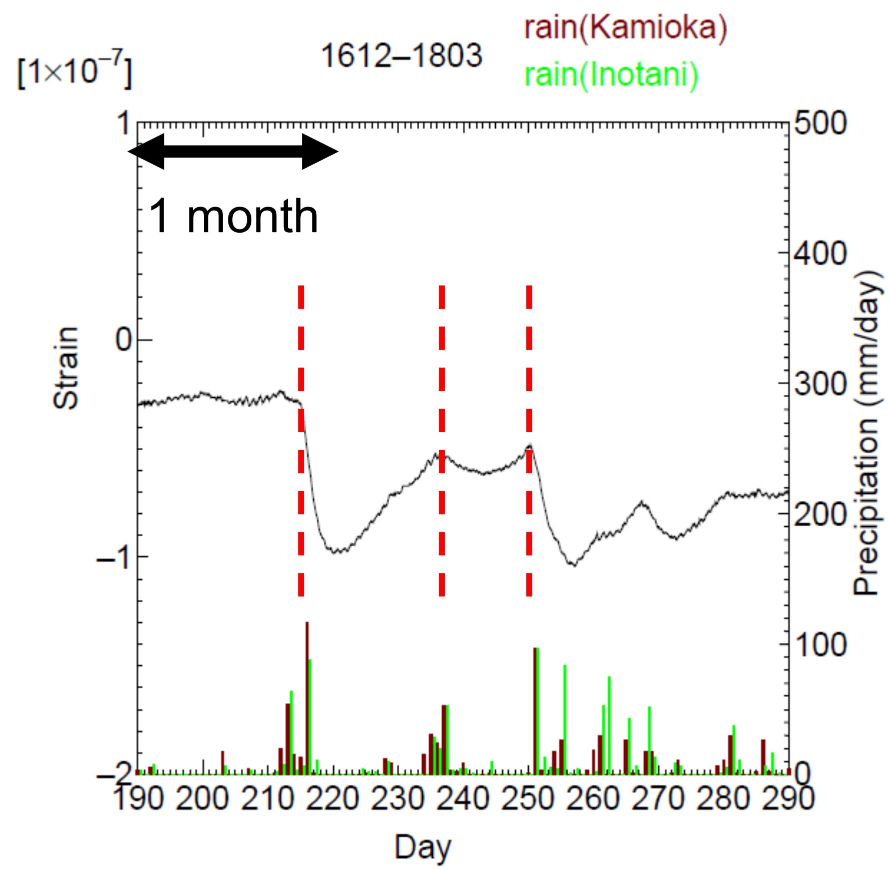
-Theoretical tides were calculated and removed

-Averaged for every 10 min.

Response to rain fall

…. due to change in water load ?

… Baseline change ($7x10^{-8}$ ->200um for a 3km arm) within a few days will occur when it rains heavily.



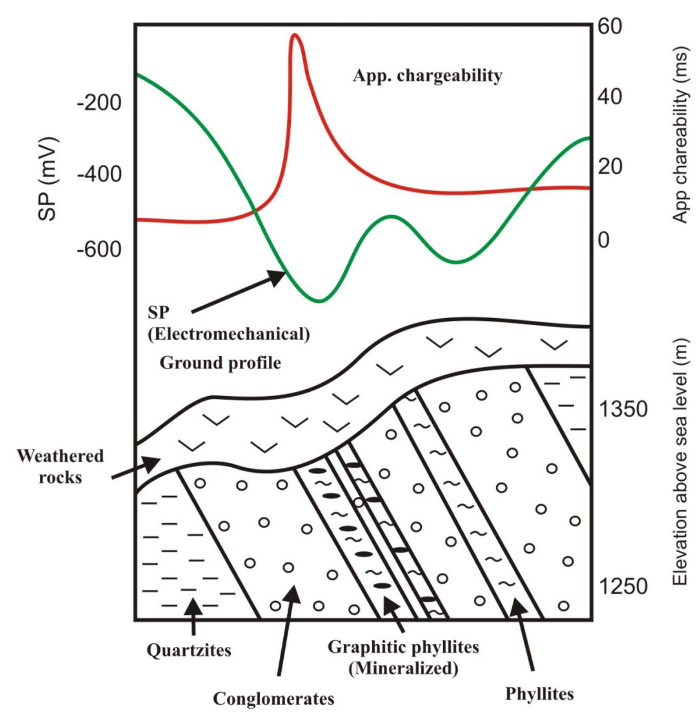
5

© A. Araya - KAGRA

f)

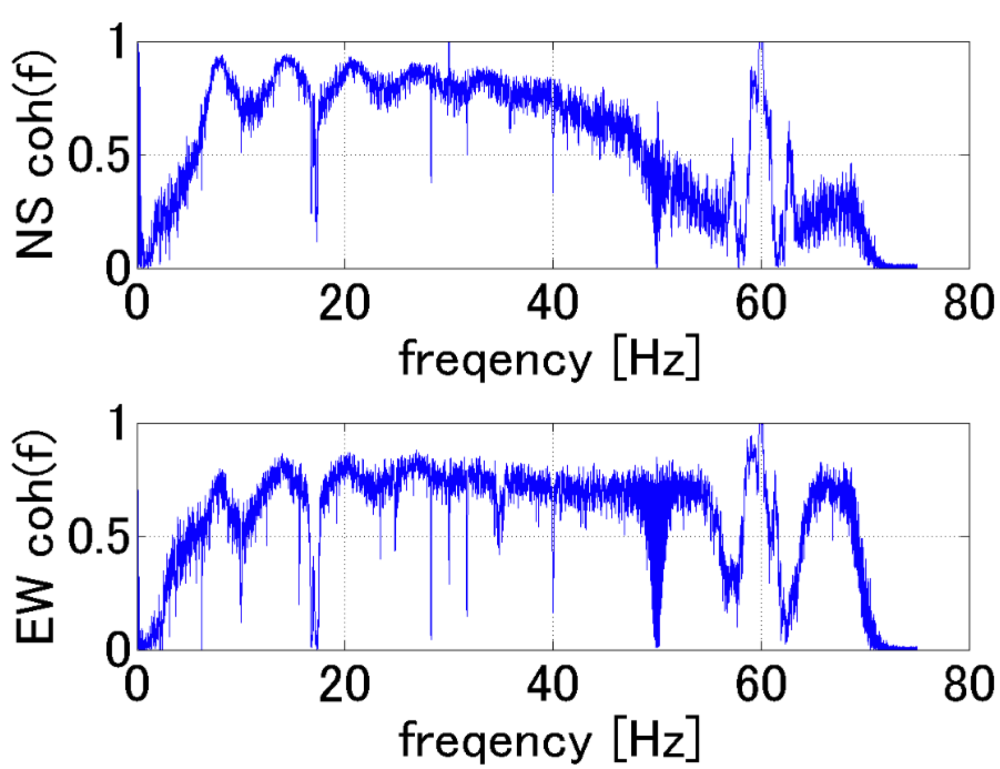
Potential differences, partly constant/partly fluctuating, are associated with electric currents in the ground. Self-potentials main mechanism have been identified: 1.Electrofiltration; 2.Diffusion; 3.Adsorption; 4.Mineral potentials.

1. An electric potential difference is developed between the ends of a capillary tube through which an electrolyte is flowing. Field is in same direction as pressure gradient, opposite to direction of electrolyte flow. Can be found associated with the flow of water through sand, porous rocks.
2. Differences in concentration of electrolytes in the ground from place to place produce electric potential differences works like a battery.
3. Adsorption of positive and negative ions on surface of veins (quartz, pegmatite).
4. Also called ‘sulphide potentials’, observed on electronically conducting materials (e.g. pyrite has one of highest potentials).



f)

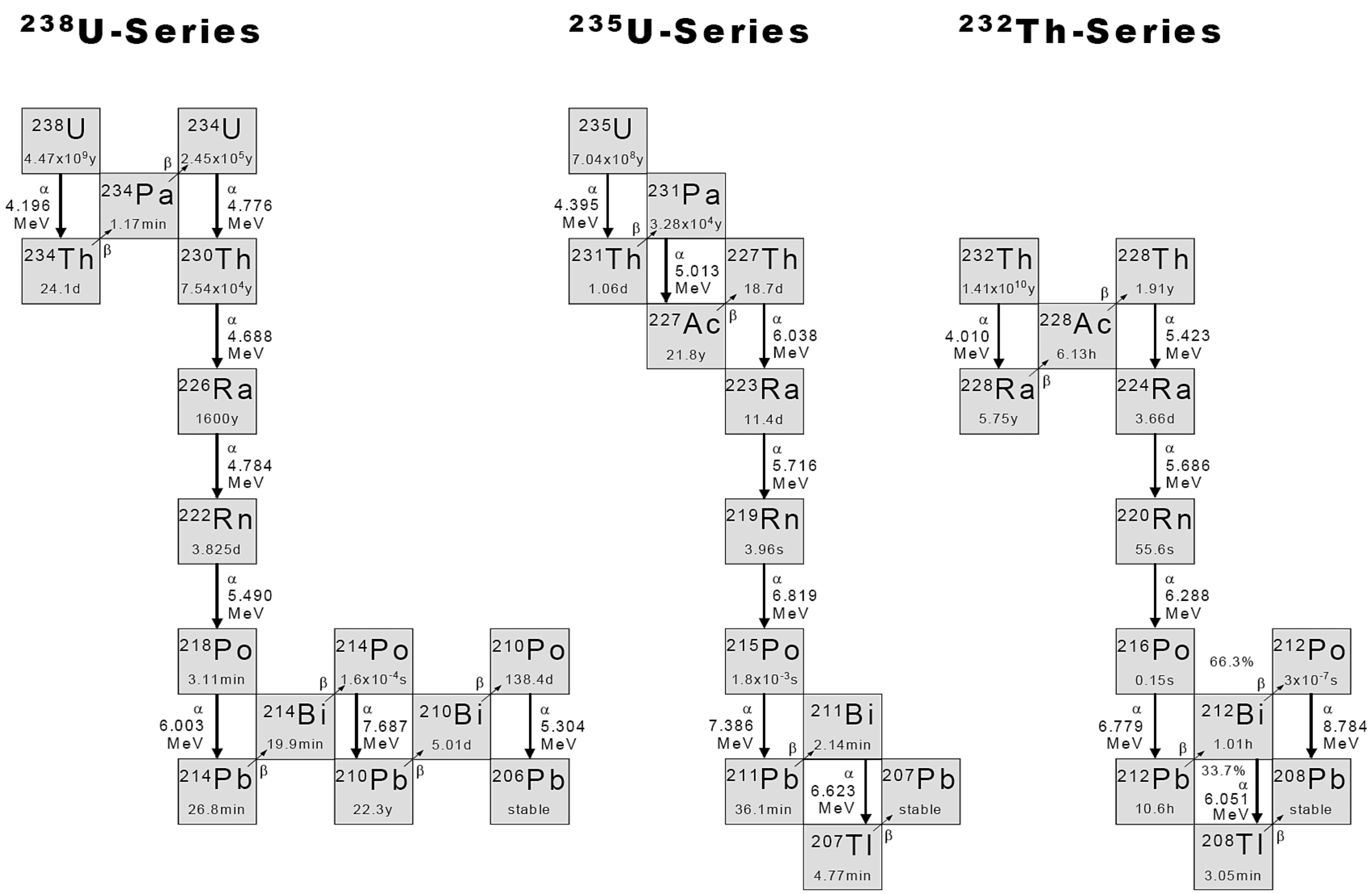
Schumann resonance is a standing wave of electromagnetic field, which occurs when a space between the surface of the Earth and the ionosphere makes a resonant cavity for electromagnetic waves. Schumann resonance is excited by lightnings that can be seen almost all over the world, and thus Schumann resonance can be seen any time from any direction.



The coherence between the signals inside and outside Kamioka. Schumann resonance comes from a corresponding direction, which is determined by the direction of the location of the lightning. High coherence indicates that the same Schumann resonance is observed both inside and outside the mine.

© doi:10.1088/1742-6596/716/1/012020

g)


238U-Series
235U-Series
232Th-Series
238U 4.47x10⁹y
234Pa 1.17min
234U 2.45x10⁵y
234Th 24.1d
230Th 7.54x10⁴y
226Ra 1600y
222Rn 3.825d
218Po 3.11min
214Bi 19.9min
214Po 1.6x10⁻⁴s
210Bi 5.01d
210Po 138.4d
214Pb 26.8min
210Pb 22.3y
206Pb stable
235U 7.04x10⁸y
231Pa 3.28x10⁴y
231Th 1.06d
227Th 18.7d
227Ac 21.8y
223Ra 11.4d
219Rn 3.96s
215Po 1.8x10⁻³s
211Bi 2.14min
211Pb 36.1min
207Pb stable
207Tl 4.77min
232Th 1.41x10¹⁰y
228Th 1.91y
228Ac 6.13h
228Ra 5.75y
224Ra 3.66d
220Rn 55.6s
216Po 0.15s
212Po 3x10⁻⁷s
212Bi 1.01h
212Pb 10.6h
208Pb stable
208Tl 3.05min
66.3%
33.7%

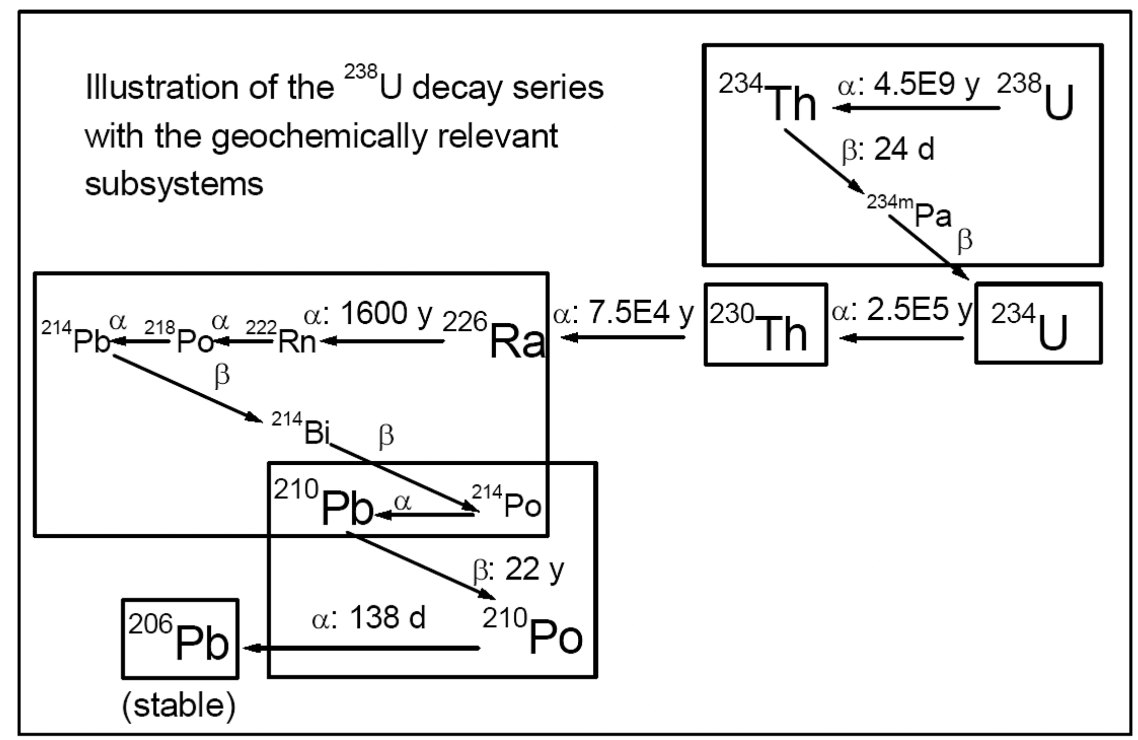
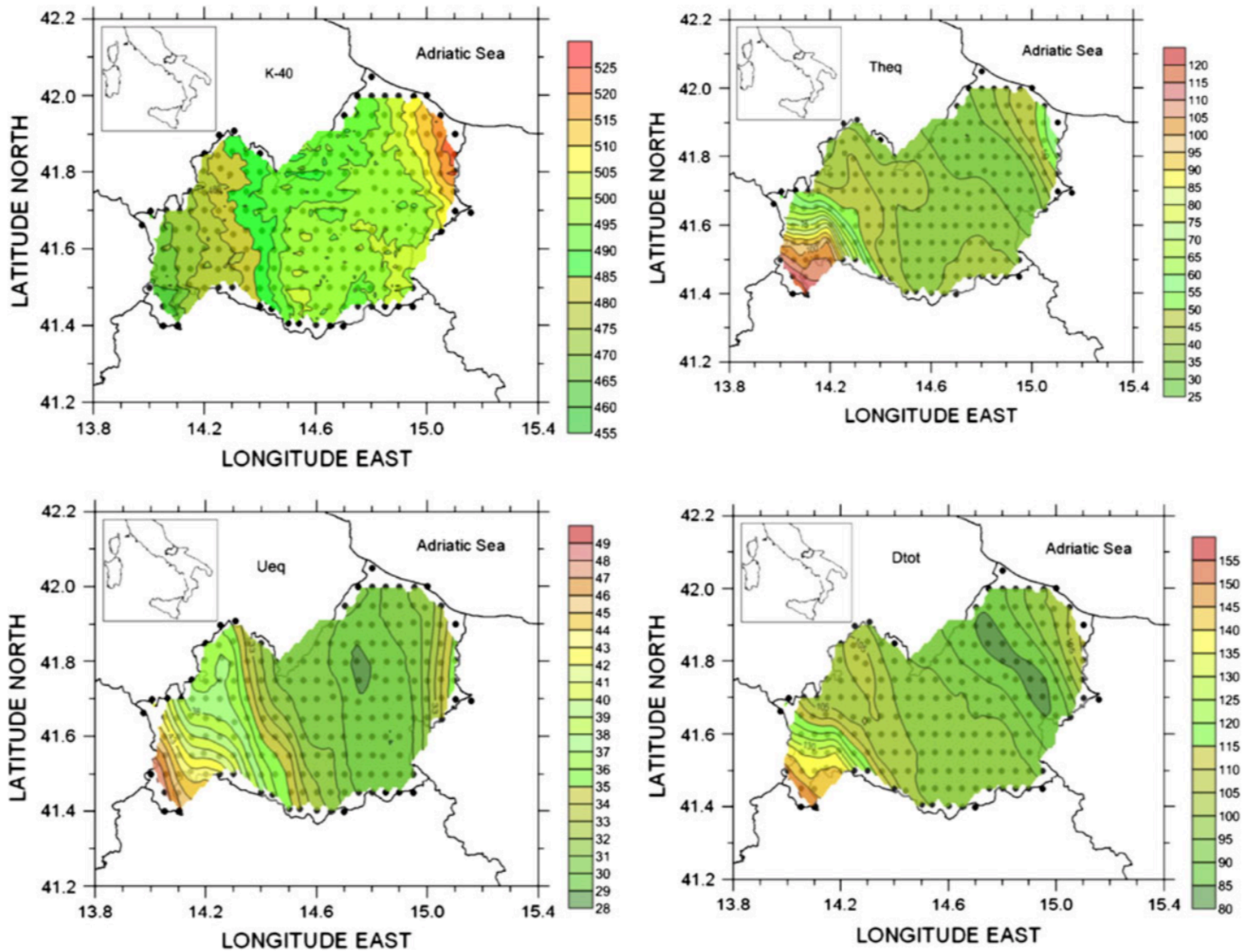


Illustration of the 238U decay series
with the geochemically relevant
subsystems
234Th α: 4.5E9 y 238U
β: 24 d
234mPa β
230Th α: 2.5E5 y 234U
α: 7.5E4 y
214Pb α 218Po α 222Rn α: 1600 y 226Ra
β
214Bi β
210Pb α 214Po
β: 22 y
206Pb α: 138 d 210Po
(stable)

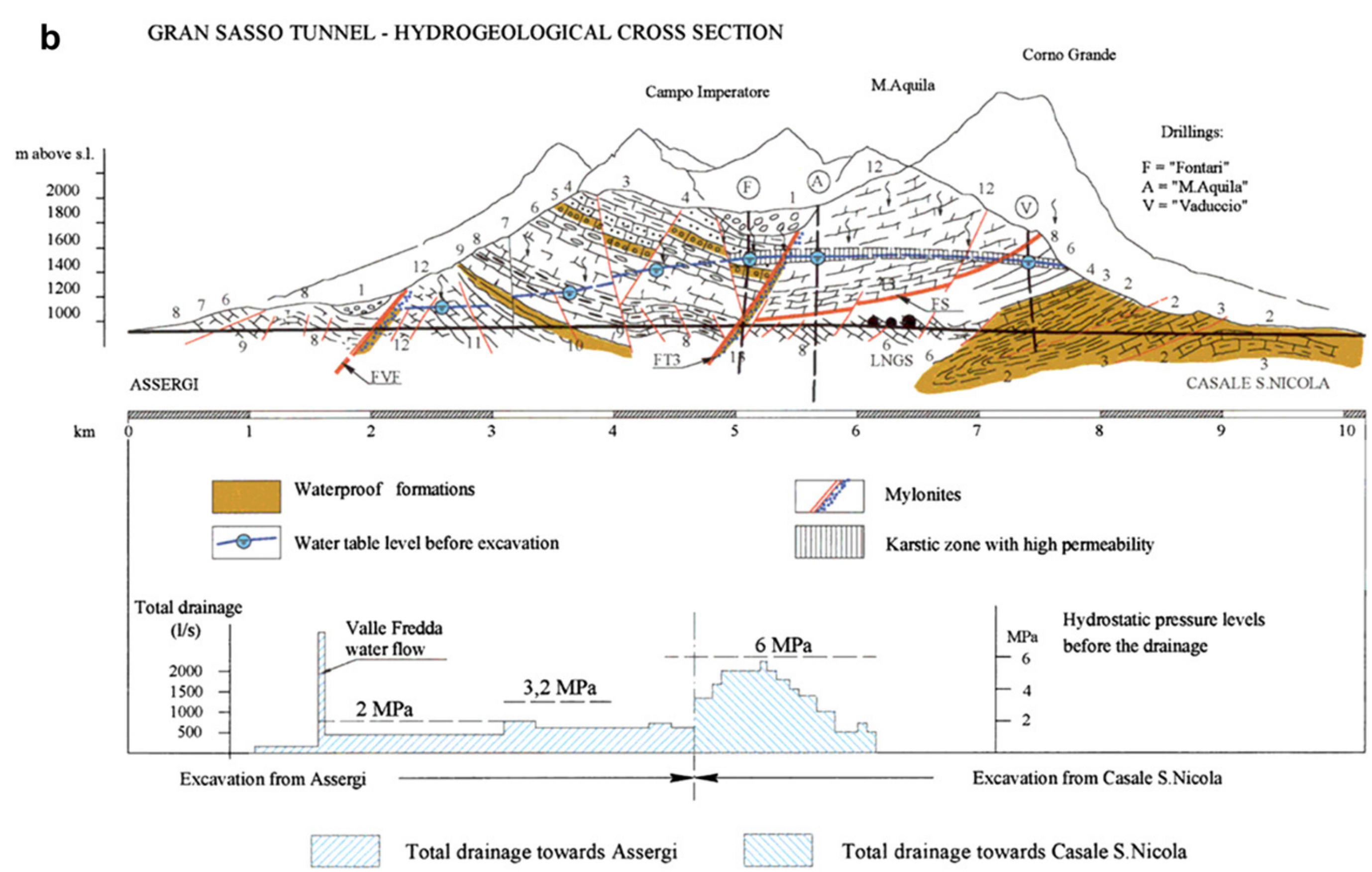
g)

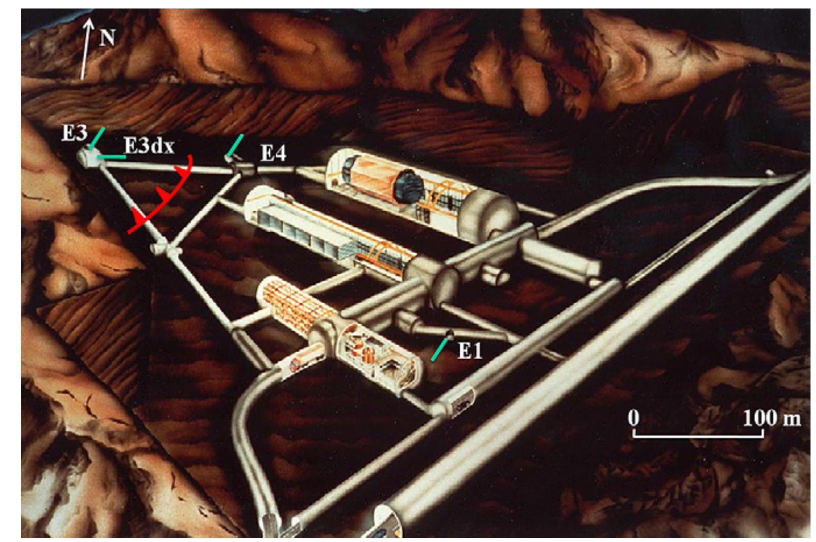


Radioactivity maps of the Molise region showing massic activities (in Bq kg^{-1}) of ^{40}K, Ueq (represented by ^{226}Ra), Theq, and the total dose rate due to natural radioactivity and cosmic radiation (in nGy h^{-1}).

© doi:10.1007/s10967-012-2353-2

g)





	U 10^{-9} g/g	^{3}H TU	^{14}C pMC	δ^{13}C ‰	δ^2H ‰	δ^{18}O ‰	pH	ORP/mV	EC µS/cm
E1	0.29 ± 0.01	6.6 ± 0.4	59.5 ± 1.0	-9.64	-72.2	-10.93	8.2 ± 0.1	231 ± 22	255.4 ± 3.0
E3	1.79 ± 0.02	8.8 ± 0.5	57.1 ± 1.0	-6.68	-74.6	-11.28	8.2 ± 0.1	232 ± 22	169.3 ± 2.0
E3dx	1.47 ± 0.02	11.2 ± 0.6			-74.4	-11.22	8.3 ± 0.1	228 ± 22	169.1 ± 2.0
E4	0.54 ± 0.01	10.1 ± 0.6	71.7 ± 1.0	-5.74	-72.6	-11.07	8.2 ± 0.1	240 ± 22	159.1 ± 2.0

© doi:10.1016/j.jenvrad.2009.08.009

	Surface	Underground
Facility	**GPS** Accelerometers Gravimeters Magnetometers	**Tiltmeters (borehole)** **Accelerometers** **Gravimeters** **Magnetometers**
Rock	**Temperature** Resistivity **Self-potential** Permeability Radioactivity	**Temperature** **Resistivity** **Self-Potential** **Permeability** Radioactivity
Fluid	**Chemistry** **Radioactivity**	**Temperature** **Pressure** **Chemistry** **Radioactivity**
Air	**Meteo (temperature, pressure, rainfall, wind, ..)** **Infrasound** **Radiaoctivity**	**Temperature** **Pressure** **Infrasound** **Radioactivity**

Conclusions

- For site selection it is necessary to plan monitoring activities including all possible environmental noises on surface as well as in underground, and considering their coupling effect too.

- For site characterization it is necessary to perform the same monitoring activities during the realization of underground infrastructures, for studying the environmental assessment of ET *vs* time.

- For safety issues it is necessary to plan and realize an environmental monitoring network underground.

- For all environmental parameters it is necessary a robust time series analysis based on adaptive methodologies.