Lecture notes

FRACTO-EMISSIONS AS SEISMIC PRECURSORS

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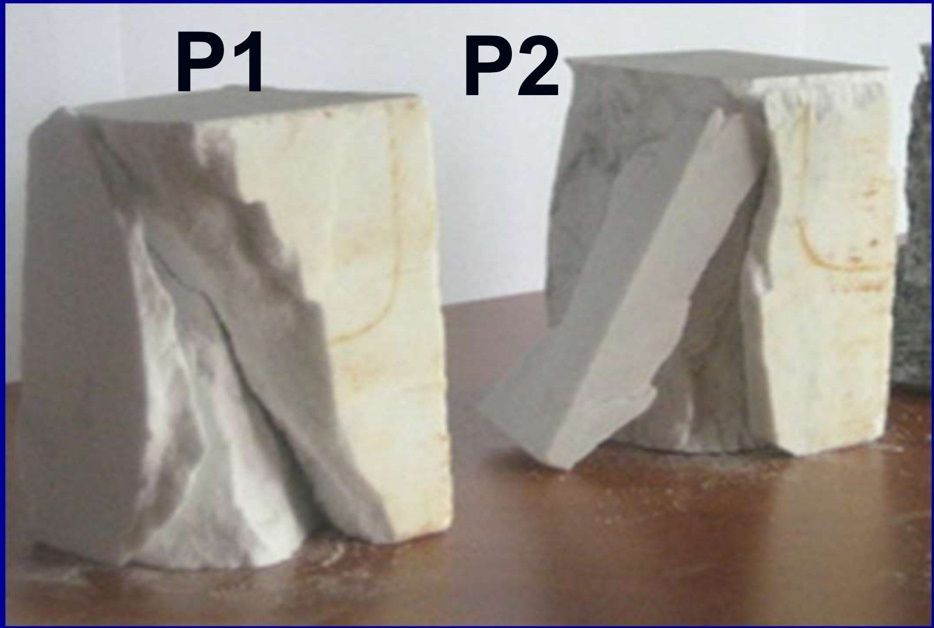
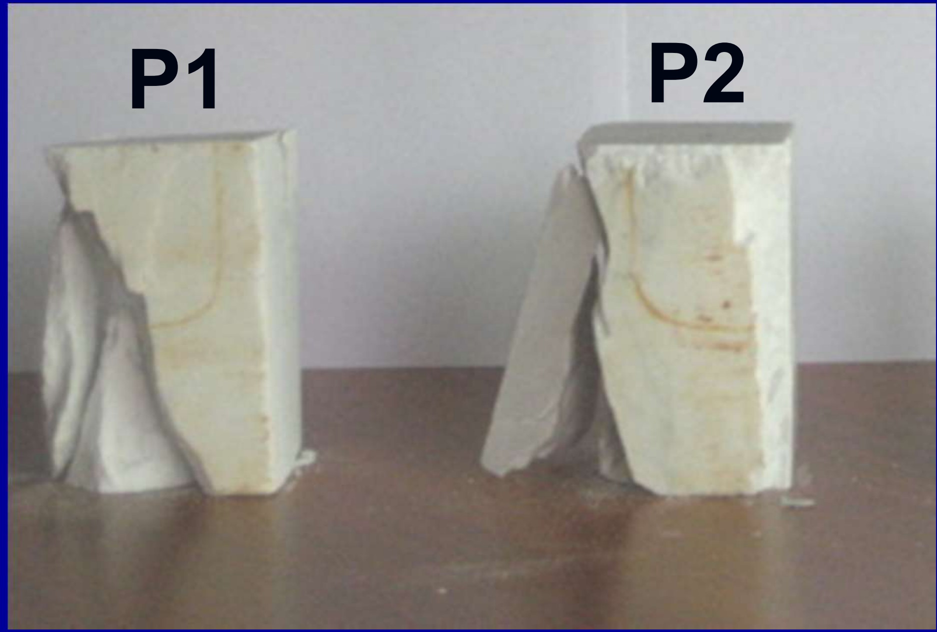
NEUTRON EMISSION FROM FRACTURE AT THE LABORATORY SCALE

NEUTRON EMISSION FROM ROCK SPECIMENS

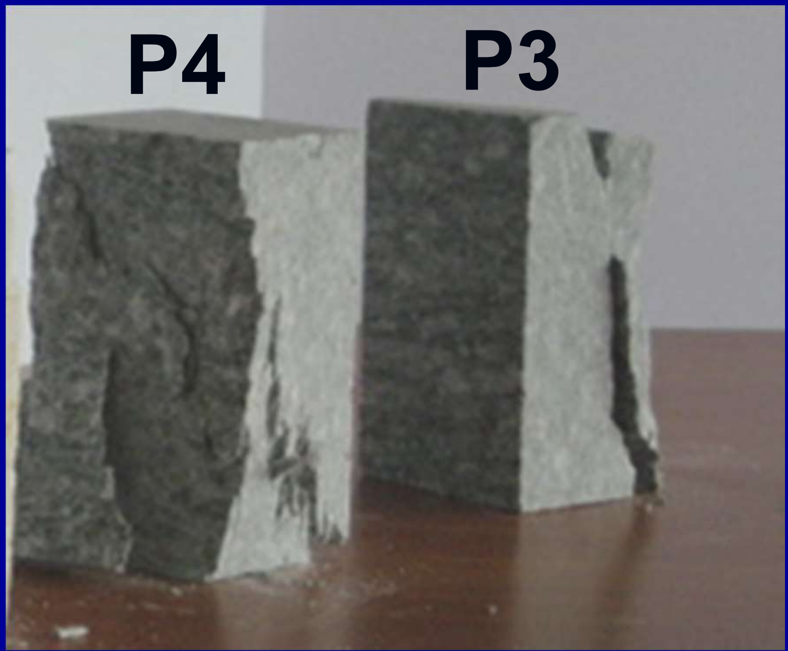
During a preliminary experimental analysis <u>four rock specimens</u> were used:

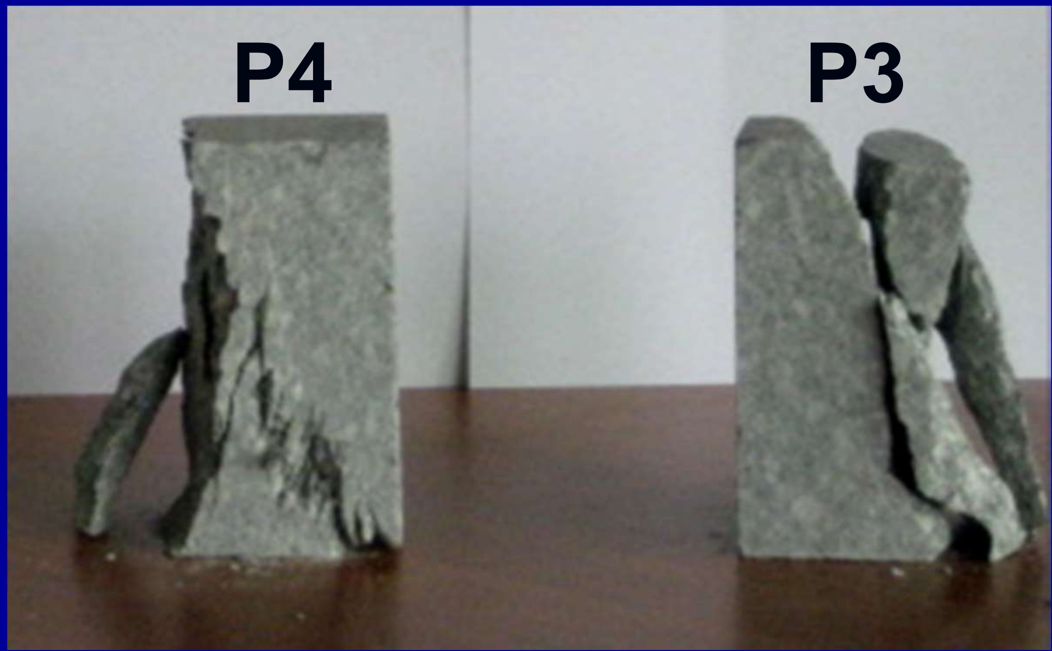
- **two made of <u>Carrara marble</u>, specimens P1 and P2;**
- **two made of <u>Luserna granite</u>, specimens P3 and P4;**
- **all of them measuring <u>6x6x10 cm^3</u>.**





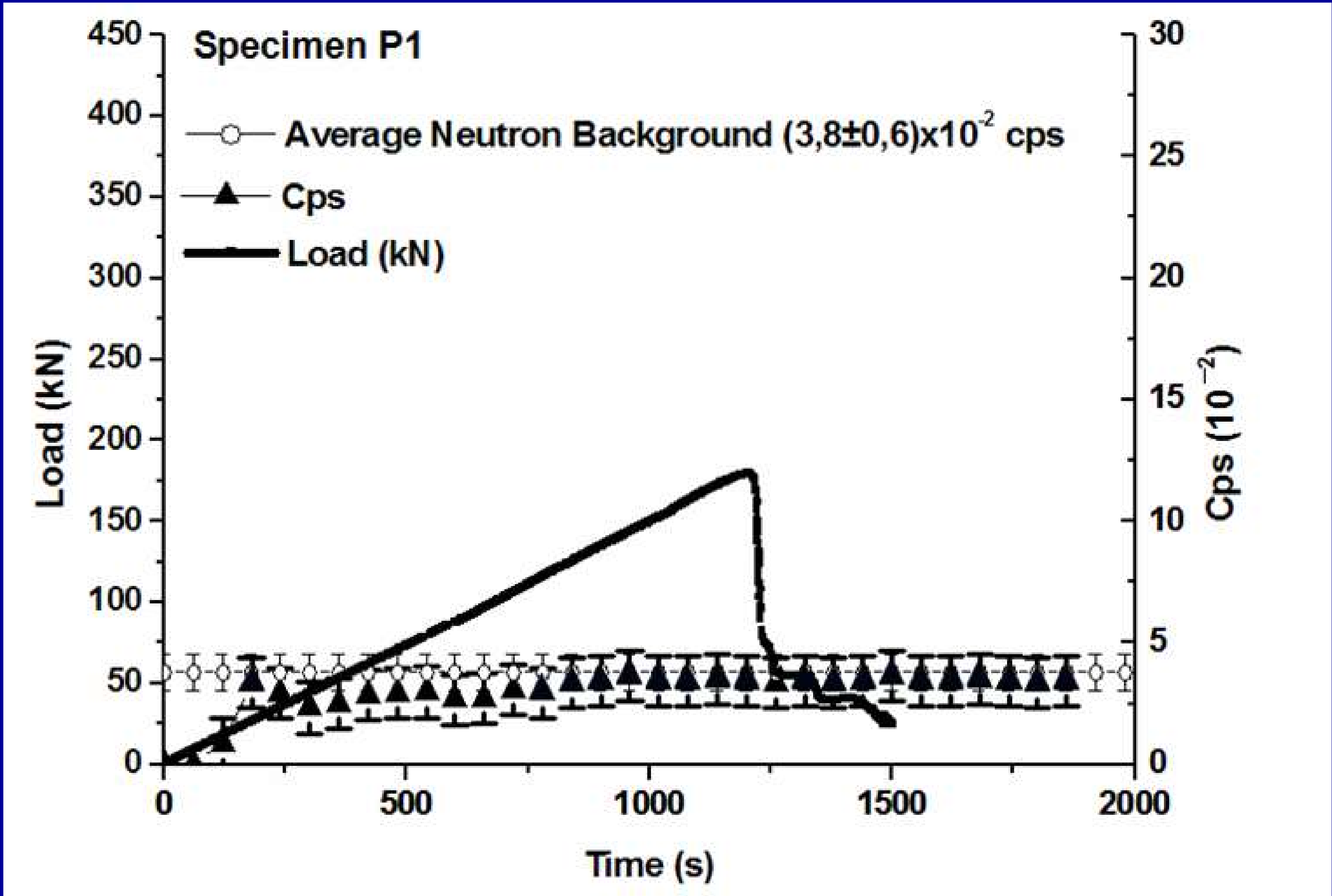
Specimens P1 and P2 in Carrara marble following compression failure.





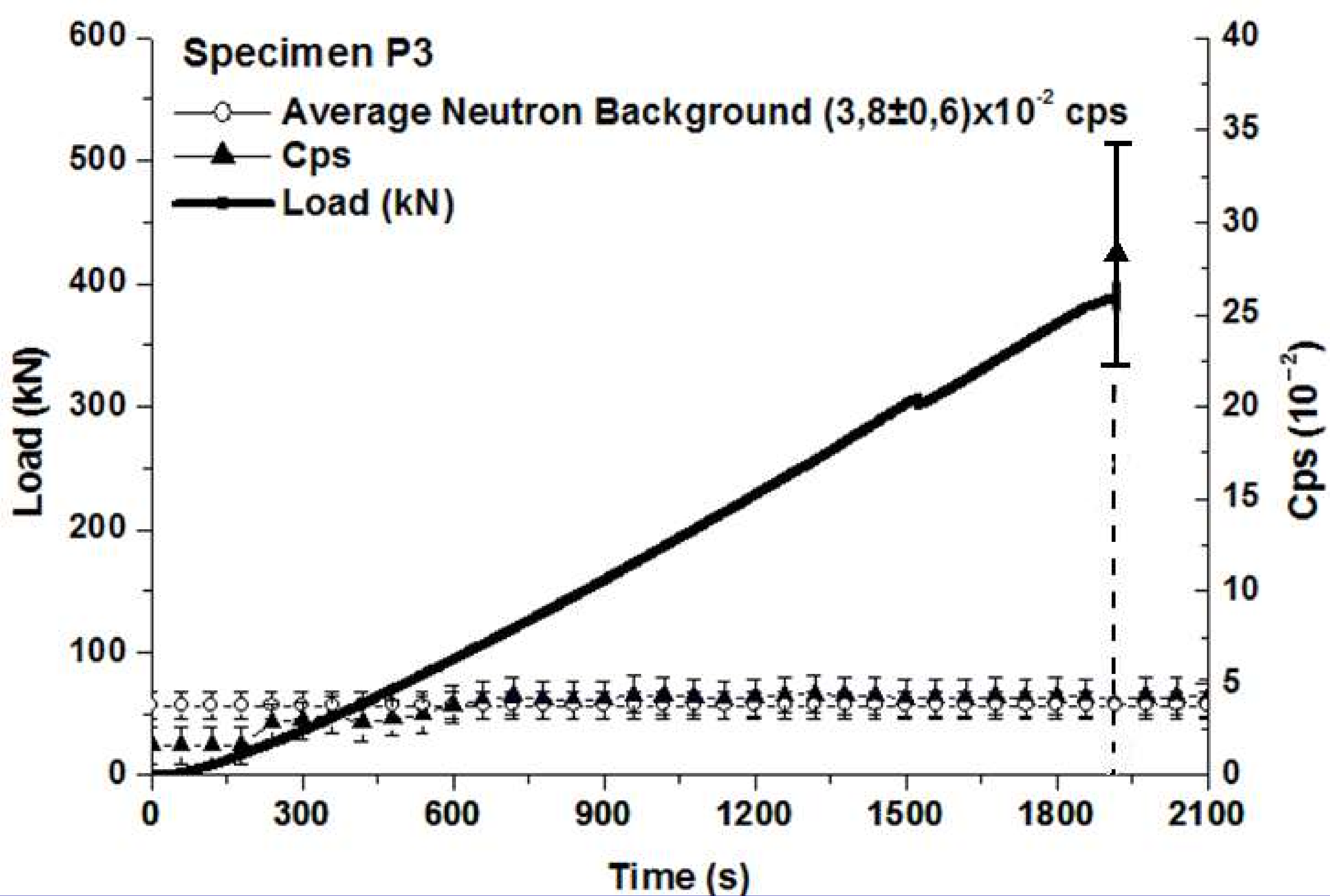
Specimens P3 and P4 in Luserna granite following compression failure.

Brittle Fracture Experiment on Carrara Marble specimen



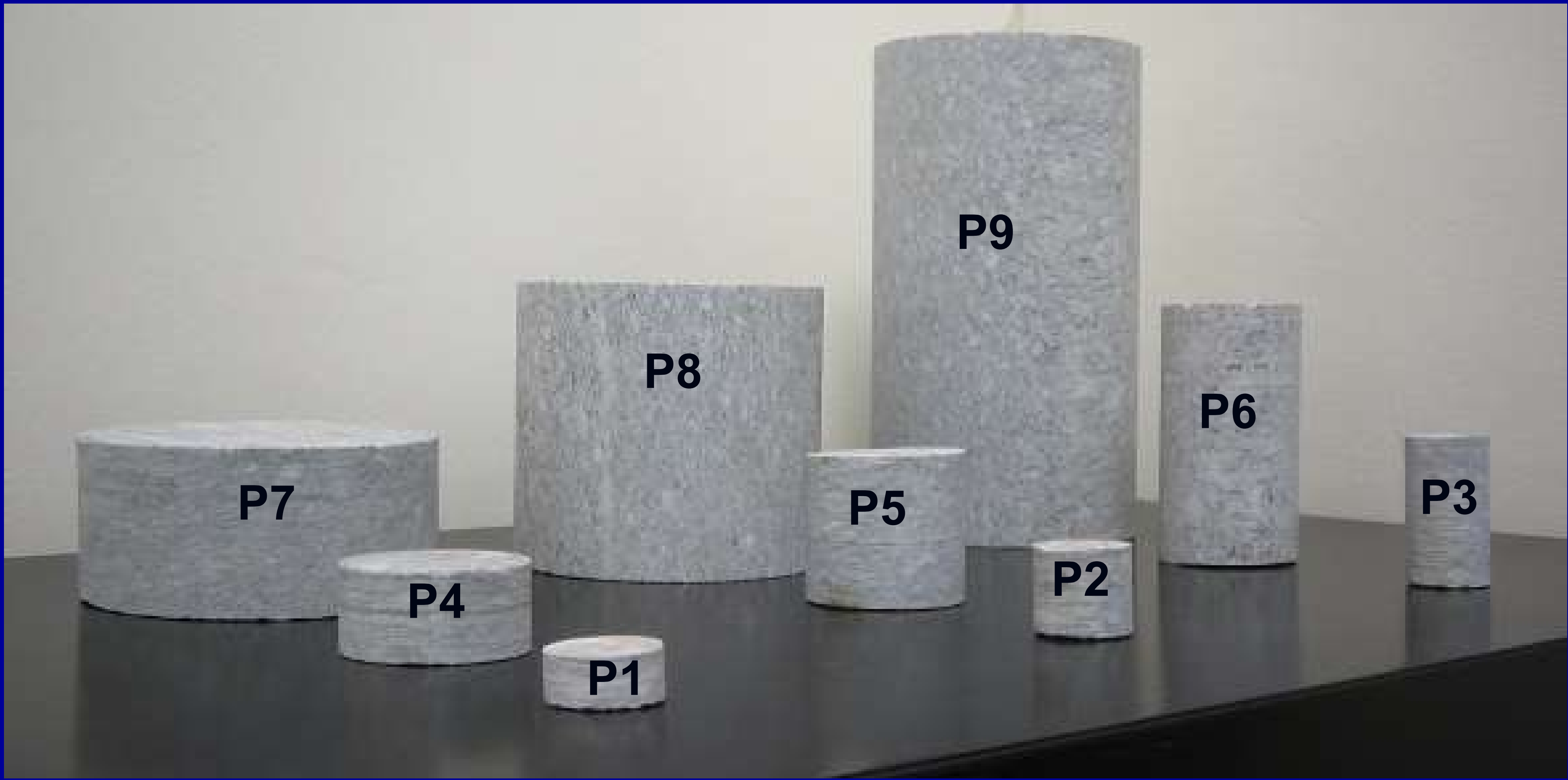
Load vs. time and cps curve for P1 test specimen of Carrara marble.

Brittle Fracture Experiment on granite specimen

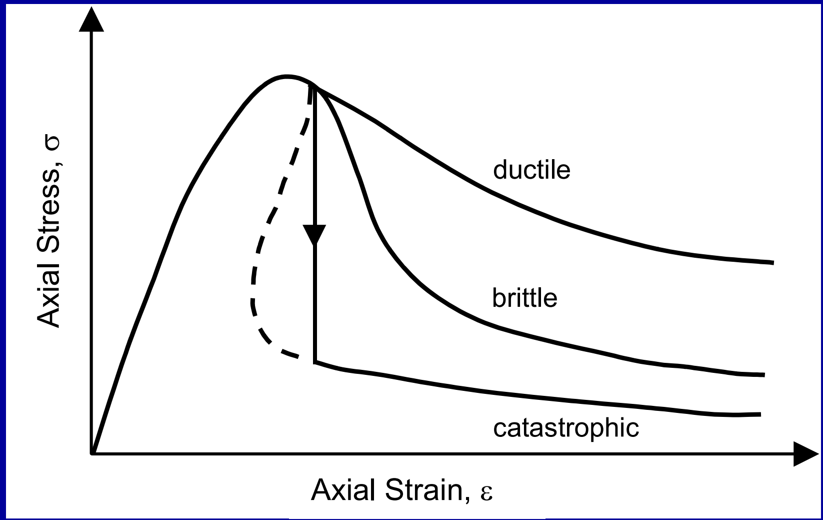


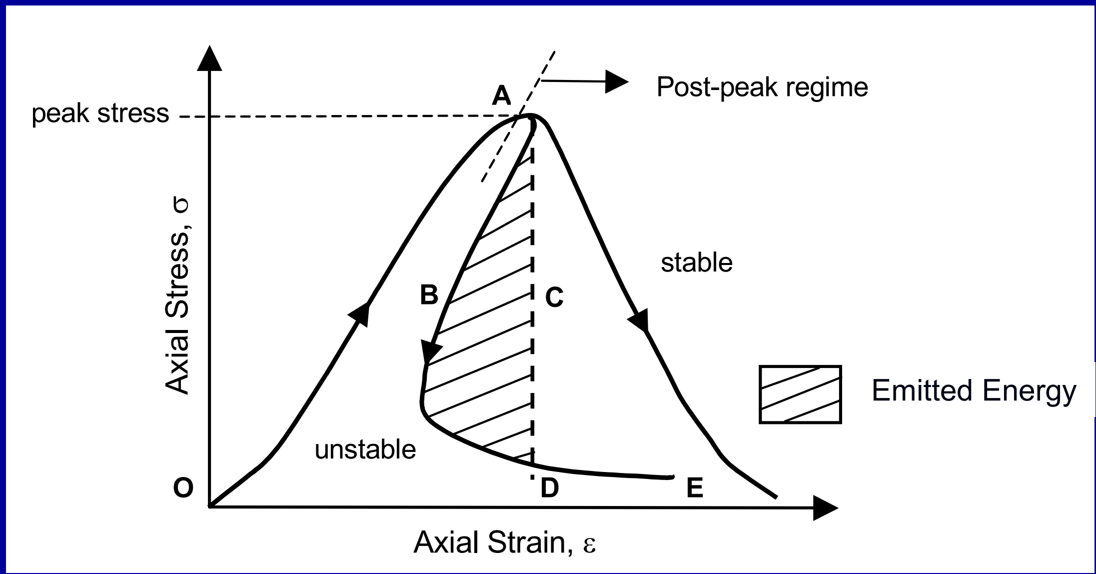
Load vs. time and cps curve for P3 test specimen of granite.

Neutron emissions were measured on nine Green Luserna stone cylindrical specimens, of different size and shape (D=28, 56, 112 mm; λ= 0.5, 1.0, 2.0)



DUCTILE, BRITTLE AND CATASTROPHIC BEHAVIOUR



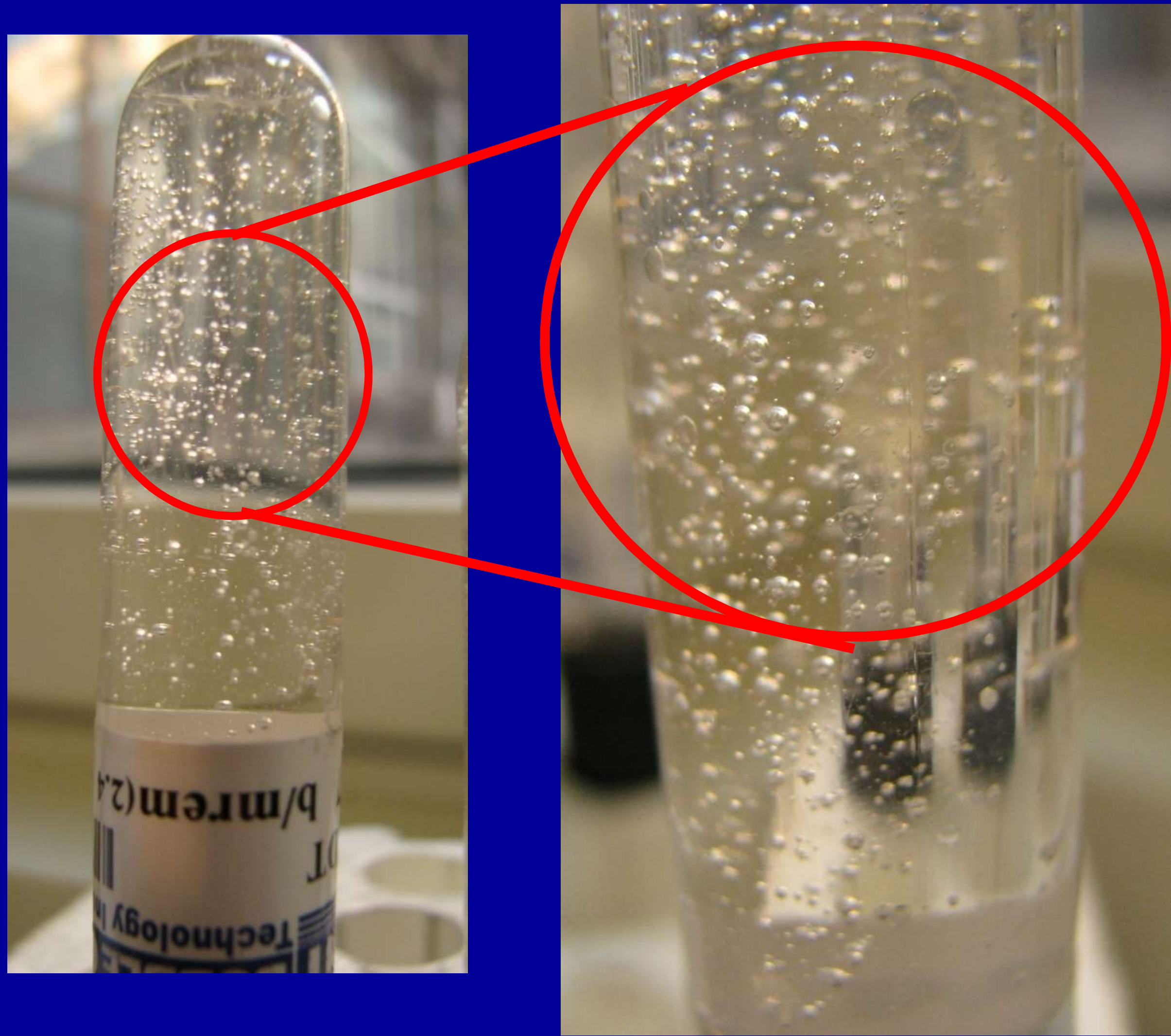


Energy emission and stable vs. unstable stress-strain behaviour

Different Materials Used in the Experimental Investigation

- Luserna stone
- Basalt
- Magnetite
- Mortar enriched with iron dioxide
- Carrara marble
- Gypsum
- Steel

Cyclic Loading Experiments on Basaltic Rocks



The equivalent neutron dose, at the end of the test on basaltic rock, was 2.62 ± 0.53 μSv/h (Average Background Dose = 41.95 ± 0.85 nSv/h).

$$\frac{\text{Effective Neutron Dose}}{\text{Average Background Dose}} \cong 50$$

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Piezonuclear neutrons from fracturing of inert solids

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Rocks crushing failure
Strain localization
Material interpenetration

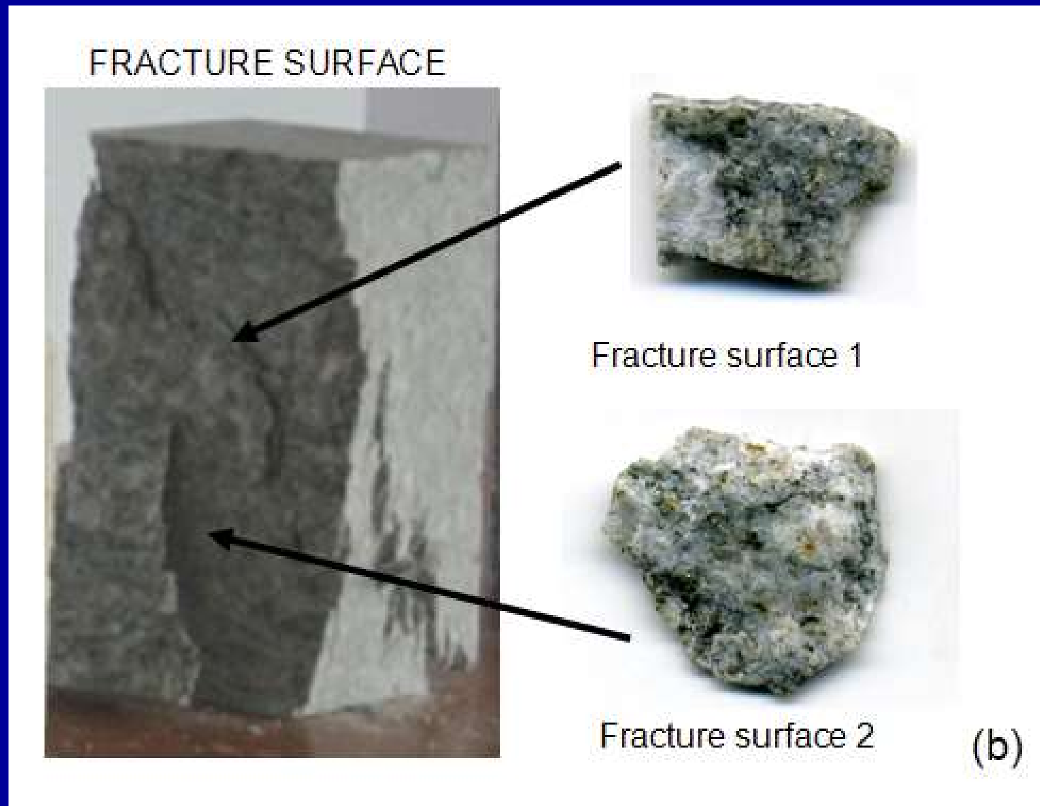
ABSTRACT

Neutron emission measurements by means of helium-3 neutron detectors were performed on solid test specimens during crushing failure. The materials used were marble and granite, selected in that they present a different behaviour in compression failure (i.e., a different brittleness index) and a different iron content. All the test specimens were of the same size and shape. Neutron emissions from the granite test specimens were found to be of about one order of magnitude higher than the natural background level at the time of failure. These neutron emissions should be caused by nucleolysis or piezonuclear "fissions" that occurred in the granite, but did not occur in the marble: $Fe^{30}_{26} \rightarrow 2Al^{14}_{13} + 2$ neutrons. The present natural abundance of aluminum (7–8% in the Earth crust), which is less favoured than iron from a nuclear point of view, is possibly due to the above piezonuclear fission reaction. Despite the apparently low statistical relevance of the results presented in this Letter, it is useful to present them in order to give to other teams the possibility to repeat the experiment.

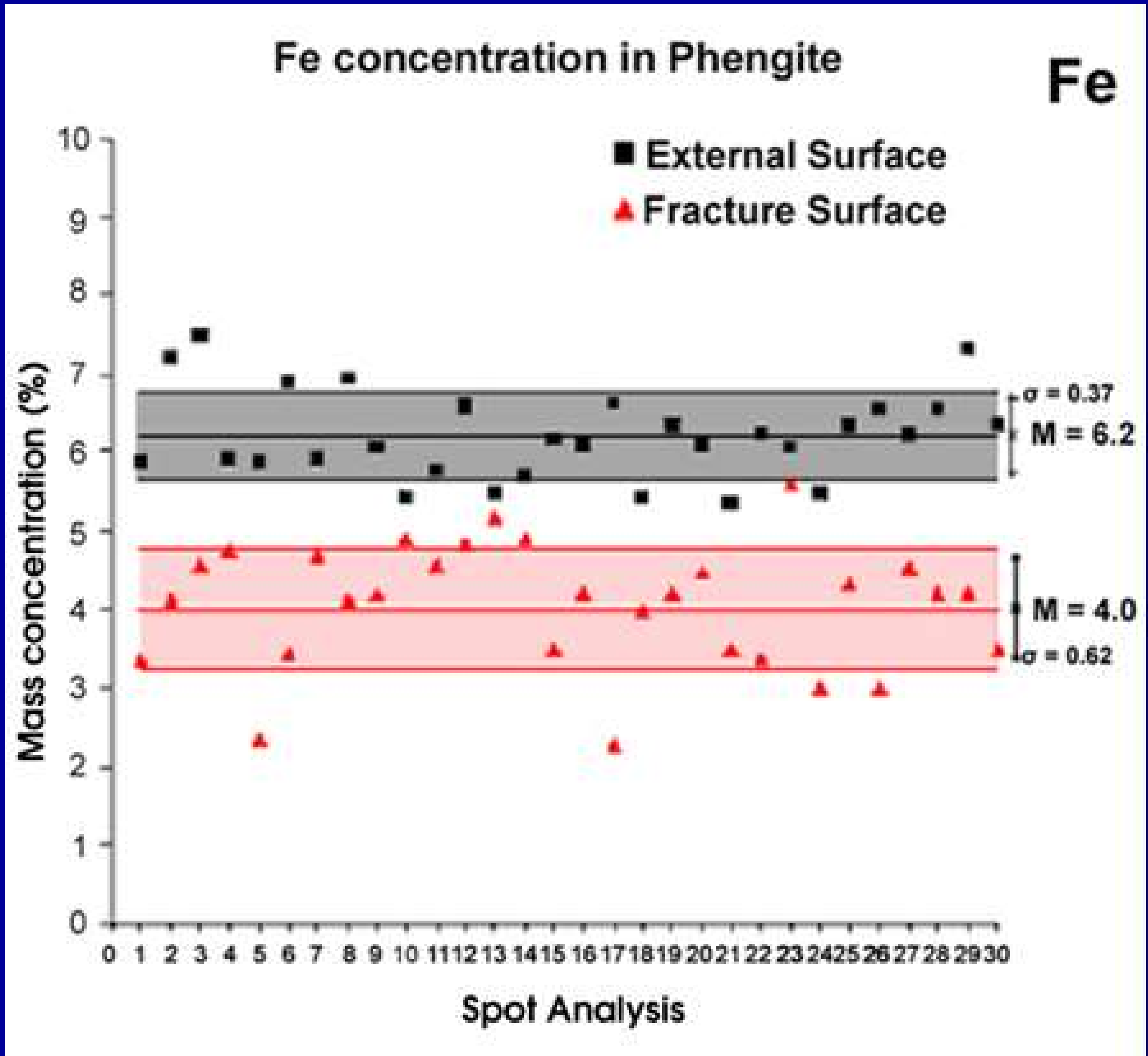
CHEMICAL COMPOSITION CHANGES AT THE LABORATORY SCALE

ENERGY DISPERSIVE X-RAY SPECTROSCOPY: COMPOSITIONAL ANALYSIS OF PRODUCT ELEMENTS

Two different kinds of samples were examined: (i) polished thin sections from the external surface; (ii) small fragments from the fracture surface.



Phengite (Granite) : Fe concentrations



External Surf.:

Fe content = <u>6.2%</u>

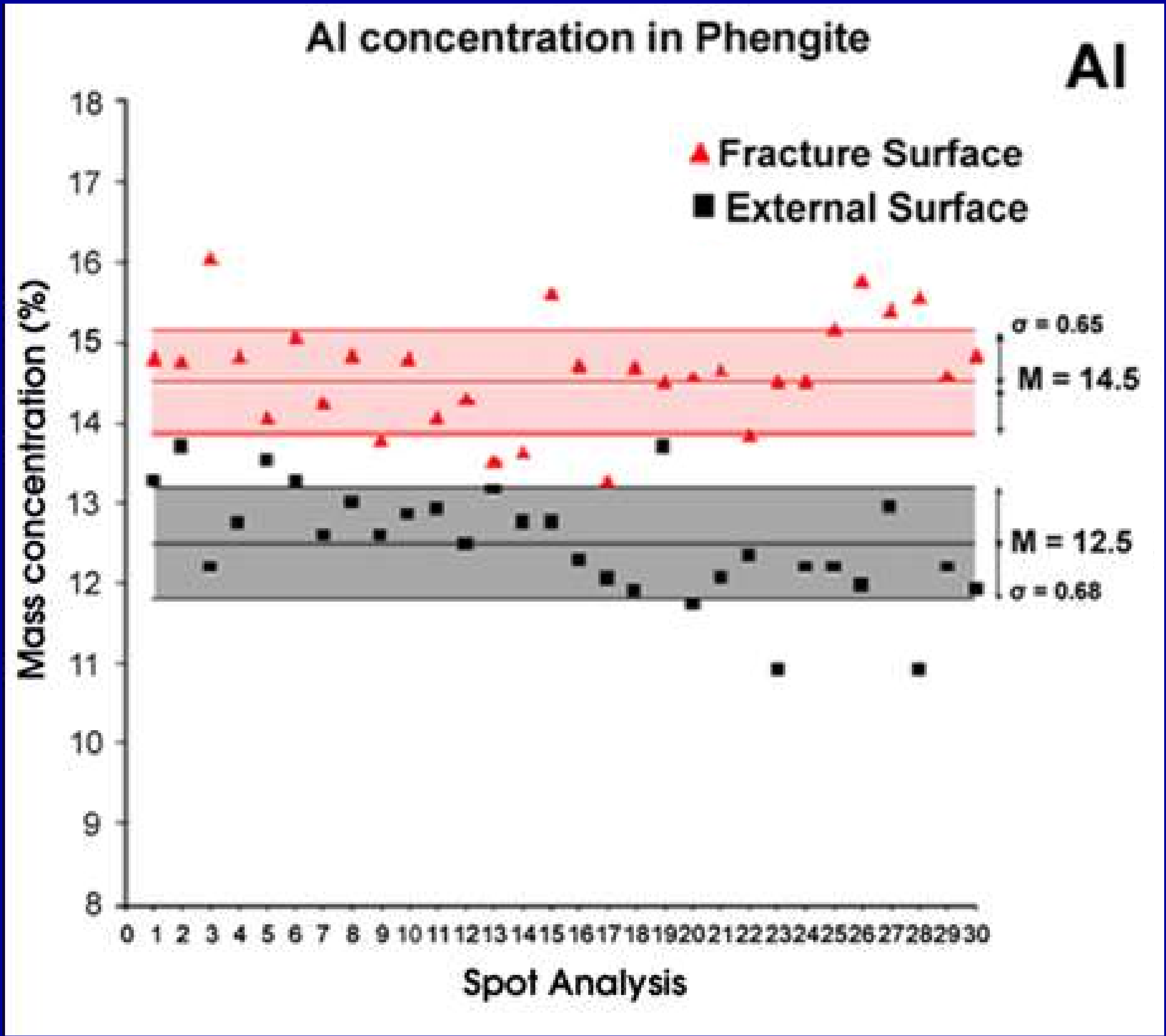
Fracture Surf.:

Fe content = <u>4.0%</u>

Fe content decrement

–2.2%

Phengite (Granite) : Al concentrations



Fracture Surf.:

Al content = <u>14.5%</u>

External Surf.:

Al content = <u>12.5%</u>

Al content increment

+2.0%

Phengite (Granite)

	External surface mean value (wt%)	Fracture surface mean value (wt%)	Increase/ decrease with respect to Phengite	Increase/ decrease with respect to the same element
Fe	6.2	4.0	– 2.2%	– 35%
Al	12.5	14.5	+ 2.0%	+ 16%
Si	28.0	27.8	NO VARIATIONS	NO VARIATIONS
Mg	0.7	0.8	NO VARIATIONS	NO VARIATIONS
K	8.0	7.7	NO VARIATIONS	NO VARIATIONS

$$Fe^{56}_{26} \rightarrow 2\,Al^{27}_{13} + 2n$$

Biotite (Granite)

	External surface mean value (wt%)	Fracture surface mean value (wt%)	Increase/ decrease with respect to Biotite	Increase/ decrease with respect to the same element
Fe	21.2	18.2	– 3.0%	– 14%
Al	8.1	9.6	+ 1.5%	+ 18%
Si	18.4	19.6	+ 1.2%	+ 6%
Mg	1.5	2.2	+ 0.7%	+ 46%
K	6.9	7.1	NO VARIATIONS	NO VARIATIONS

$$Fe^{56}_{26} \rightarrow 2\,Al^{27}_{13} + 2n$$

$$Fe^{56}_{26} \rightarrow Mg^{24}_{12} + Si^{28}_{14} + 4n$$

Carrara Marble

	External surface mean value (wt%)	Fracture surface mean value (wt%)	Increase/ decrease with respect to Carrara Marble	Increase/ decrease with respect to the same element
Ca	13.4	9.8	– 3.6%	– 26%
Mg	0.7	0.3	– 0.4%	– 57%
O	45.8	36.8	– 9.0%	– 19%
C	40.1	53.1	+ 13.0%	+ 32%

$$Ca_{20}^{40} \rightarrow 3C_6^{12} + He_2^4$$

$$Mg_{12}^{24} \rightarrow 2C_6^{12}$$

$$O_8^{16} \rightarrow C_6^{12} + He_2^4$$

strain
An International Journal for Experimental Mechanics

Compositional and Microchemical Evidence of Piezonuclear Fission Reactions in Rock Specimens Subjected to Compression Tests

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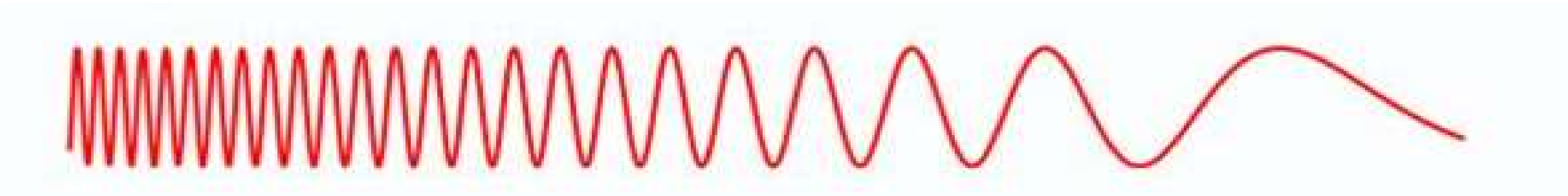
ABSTRACT: Energy-dispersive X-ray spectroscopy (EDS) is performed on different samples of external or fracture surfaces belonging to specimens used in piezonuclear tests [*Strain* 45, 2009, 332; *Strain* (in press); Phys. Lett. A. 373, 2009, 4158]. For each sample, different measurements of the same crystalline phases (phengite or biotite) are performed to obtain averaged information of the chemical composition and to detect possible piezonuclear transmutations from iron to lighter elements. The samples were carefully chosen to investigate and compare the same minerals both before and after the crushing failure. Phengite and biotite, which are quite common in the Luserna stone (20 and 2%, respectively), are considered owing to the high iron concentration in their chemical compositions. The results of EDS analyses show that, on the fracture surface samples, a considerable reduction in the iron content (∼25%) is counterbalanced by an increase in Al, Si, and Mg concentrations.

KEY WORDS: *compressive tests, energy-dispersive X-ray spectroscopy, piezonuclear reactions*

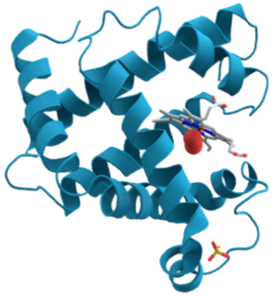
 Strain (2011) **47** (Suppl. 2), 282–292

NEUTRON EMISSION FROM FRACTURE AT THE PLANETARY SCALE

WAVELENGTH vs FREQUENCY



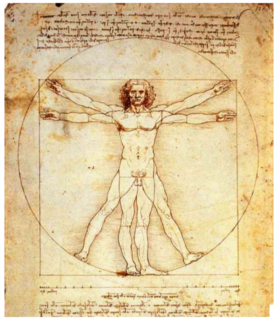
f (Hertz): 10^{12} — 10^{9} — 10^{6} — 10^{3} — 10^{0}



Proteins

Bacteria

Insects



Humans

Earthquakes

λ (Metre): 10^{-9} — 10^{-6} — 10^{-3} — 10^{0} — 10^{3}

$$\textit{wave velocity} = \lambda \times f \approx 10^{3}\ \mathrm{m\ s^{-1}}$$

FRACTO-EMISSIONS MEASUREMENT

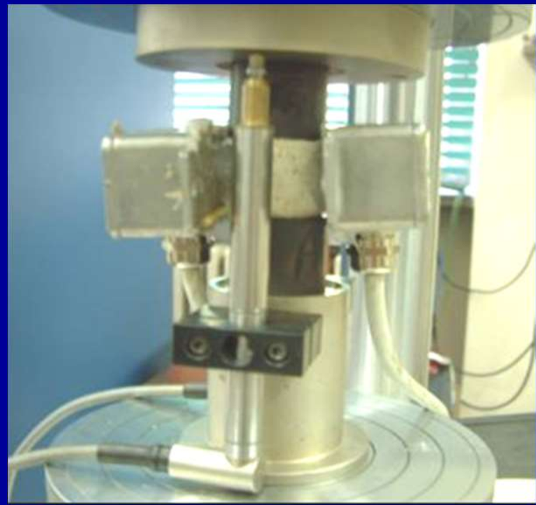
NEUTRON DETECTOR

Neutron Emission (THz – GHz)

TELESCOPIC ANTENNA

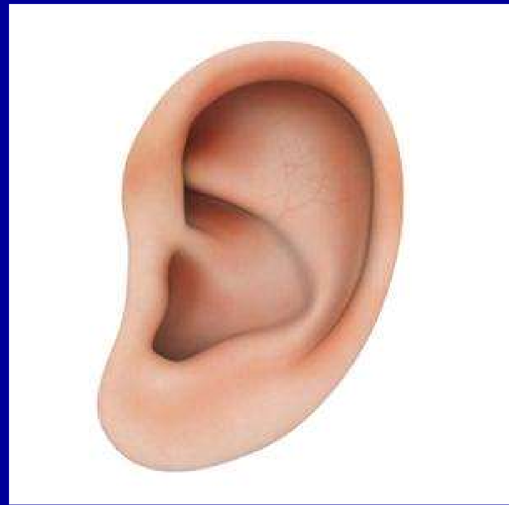
Electromagnetic Emission (GHz – MHz)

PZT TRANSDUCER



Ultrasonic Acoustic Emission (MHz – kHz)

HUMAN EAR



Audible Field (kHz – Hz)

PLANCK EQUATION

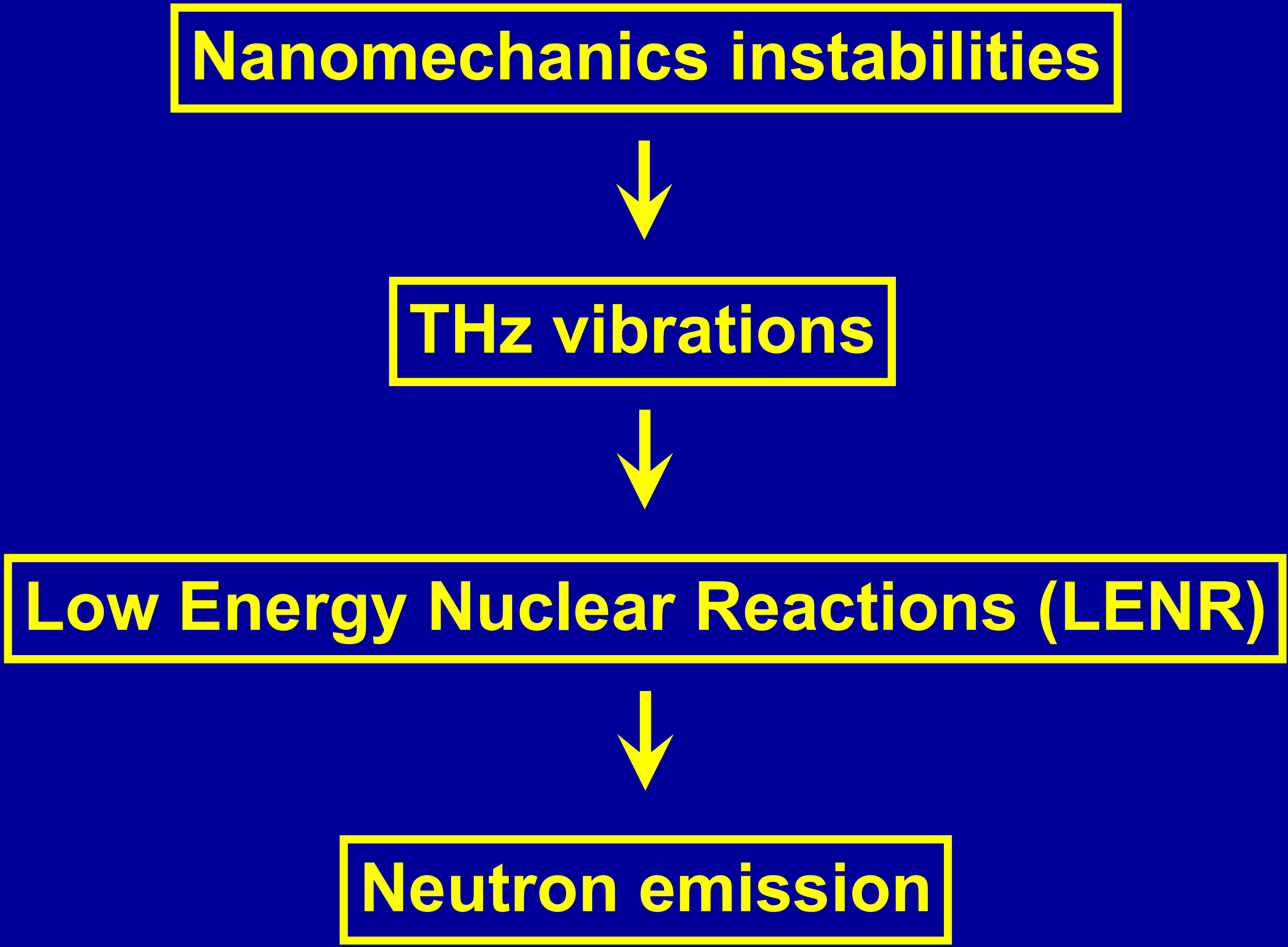
$$E = h \times f$$

Energy vs Frequency

$$0.025 \text{ eV} = (4.13 \times 10^{-15}) \text{ eVs} \times (6.05 \times 10^{12}) \text{ s}^{-1}$$

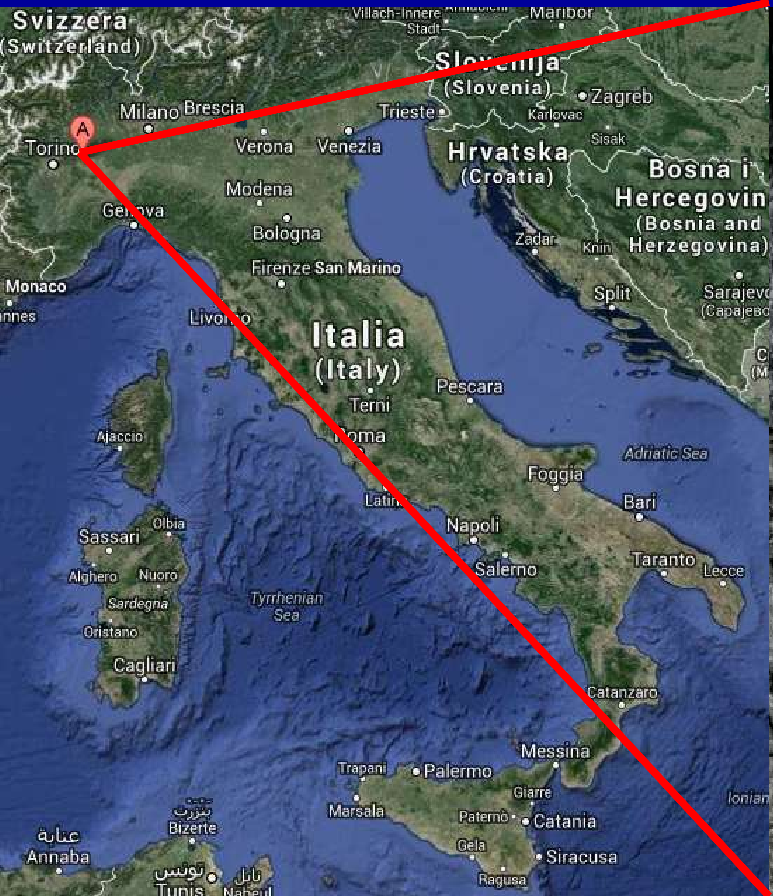
(1) TeraHertz phonons present an energy equivalent to that of thermal neutrons

(2) TeraHertz phonons present a frequency equivalent to the Debye frequency (atomic lattice resonance at 6.24 THz for U, 7.77 THz for Fe, 4.79 THz for Ca)


Nanomechanics instabilities
THz vibrations
Low Energy Nuclear Reactions (LENR)
Neutron emission

MONITORING OF A GYPSUM MINE IN MURISENGO (ITALY)

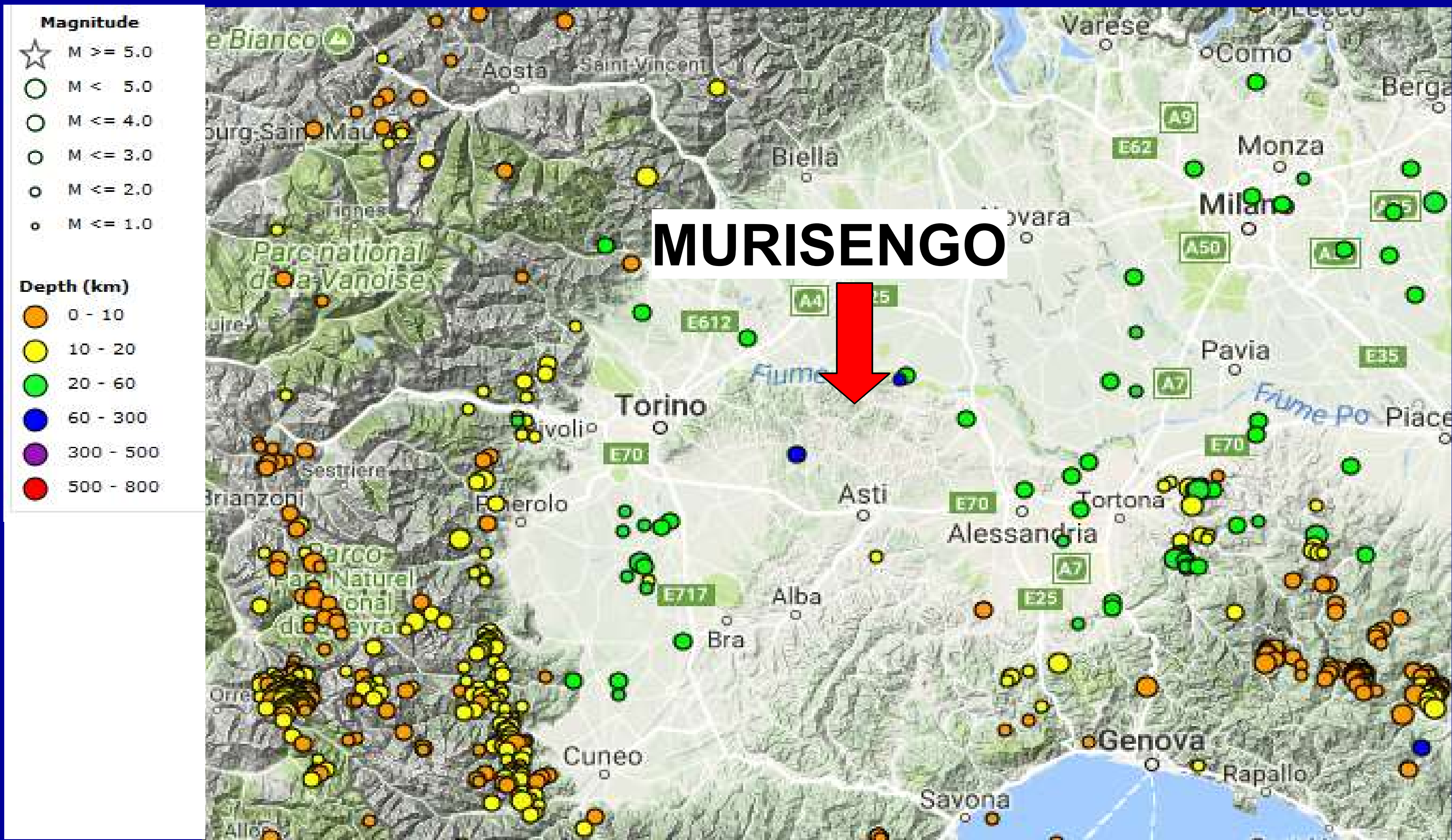
The mine is structured in five levels and a pillar located at about 100 meters underground has been subjected to a multi-parameter monitoring since July 1st, 2013.



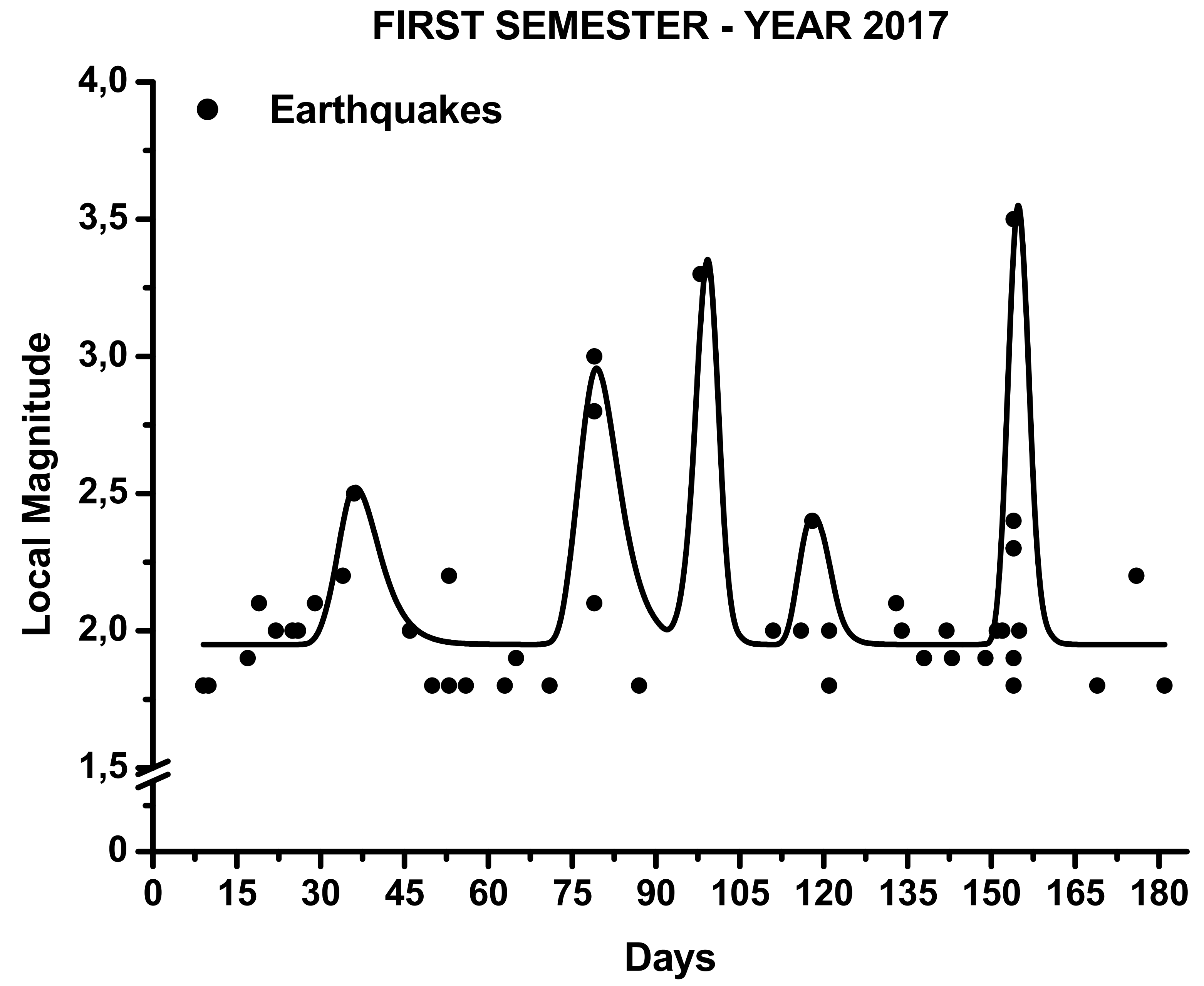
Seismic activity: July 1st, 2013 – June 30, 2019, at a distance ≤ 100 km

572 earthquakes with a local magnitude ≥ 1.8 (Richter)

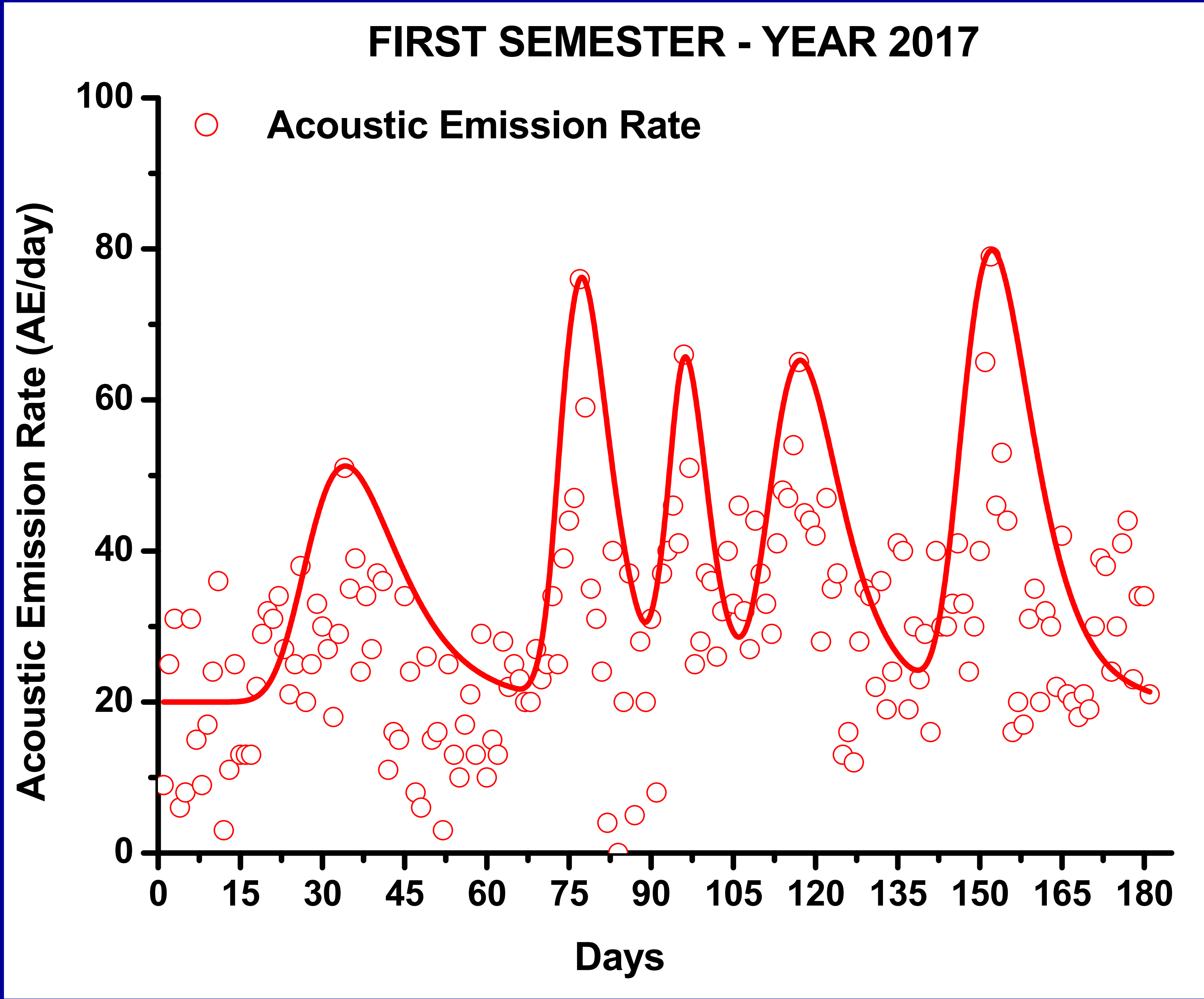
63 seismic swarms (epicentre magnitude 2.5 – 4.7)



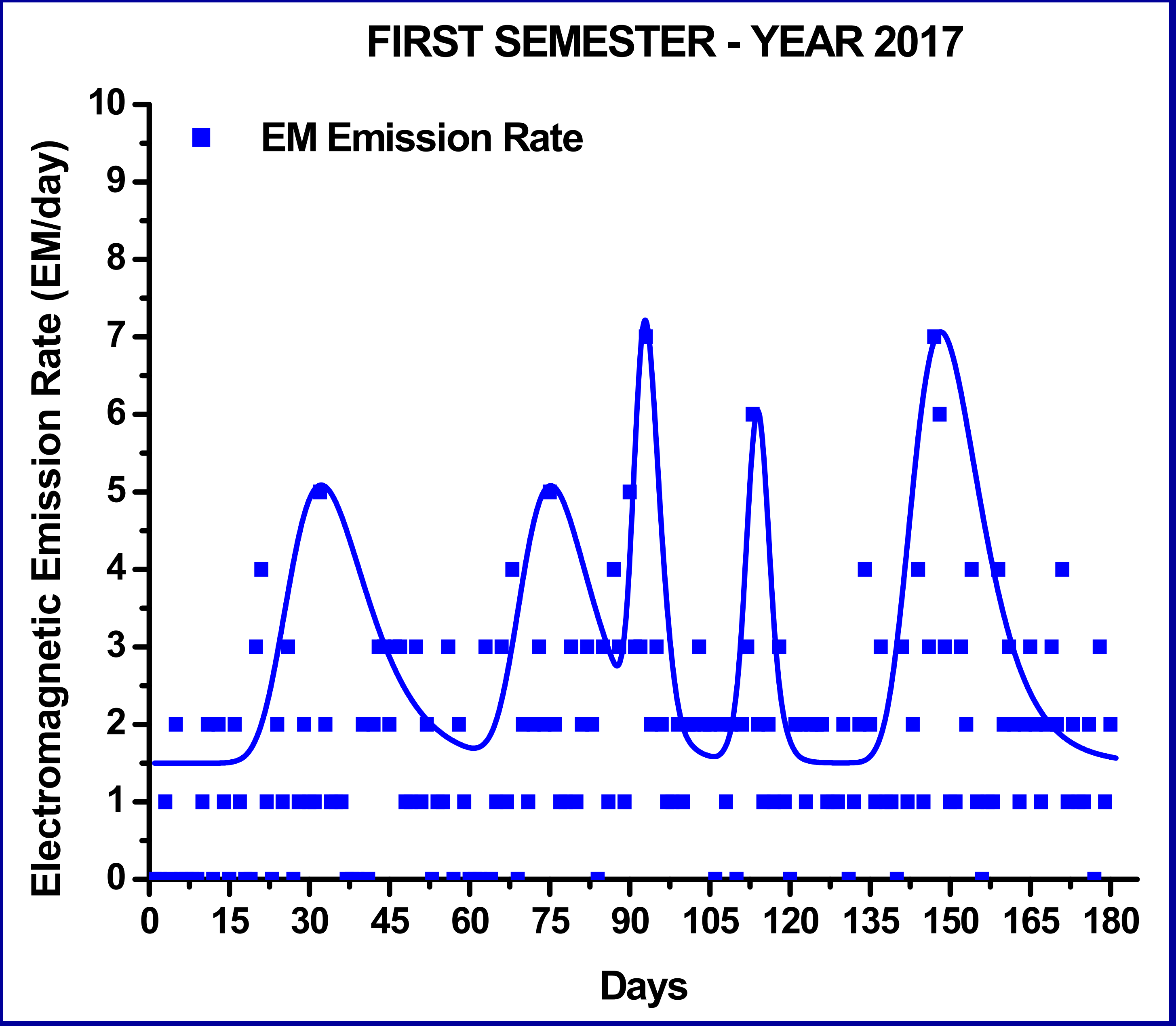
EARTHQUAKE MULTI-MODAL ANALYSIS (First Sem. 2017)



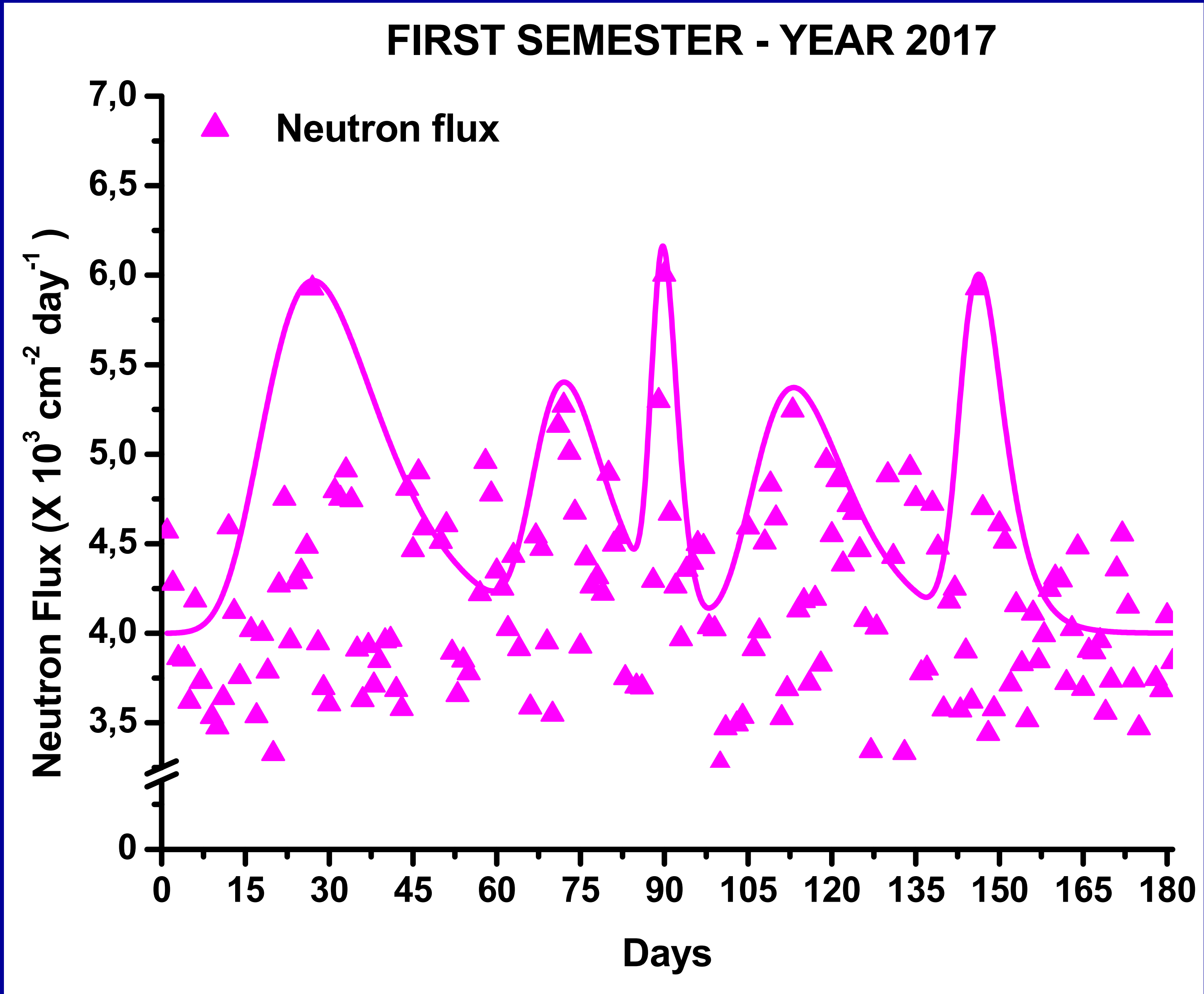
AE MULTI-MODAL ANALYSIS (First Sem. 2017)



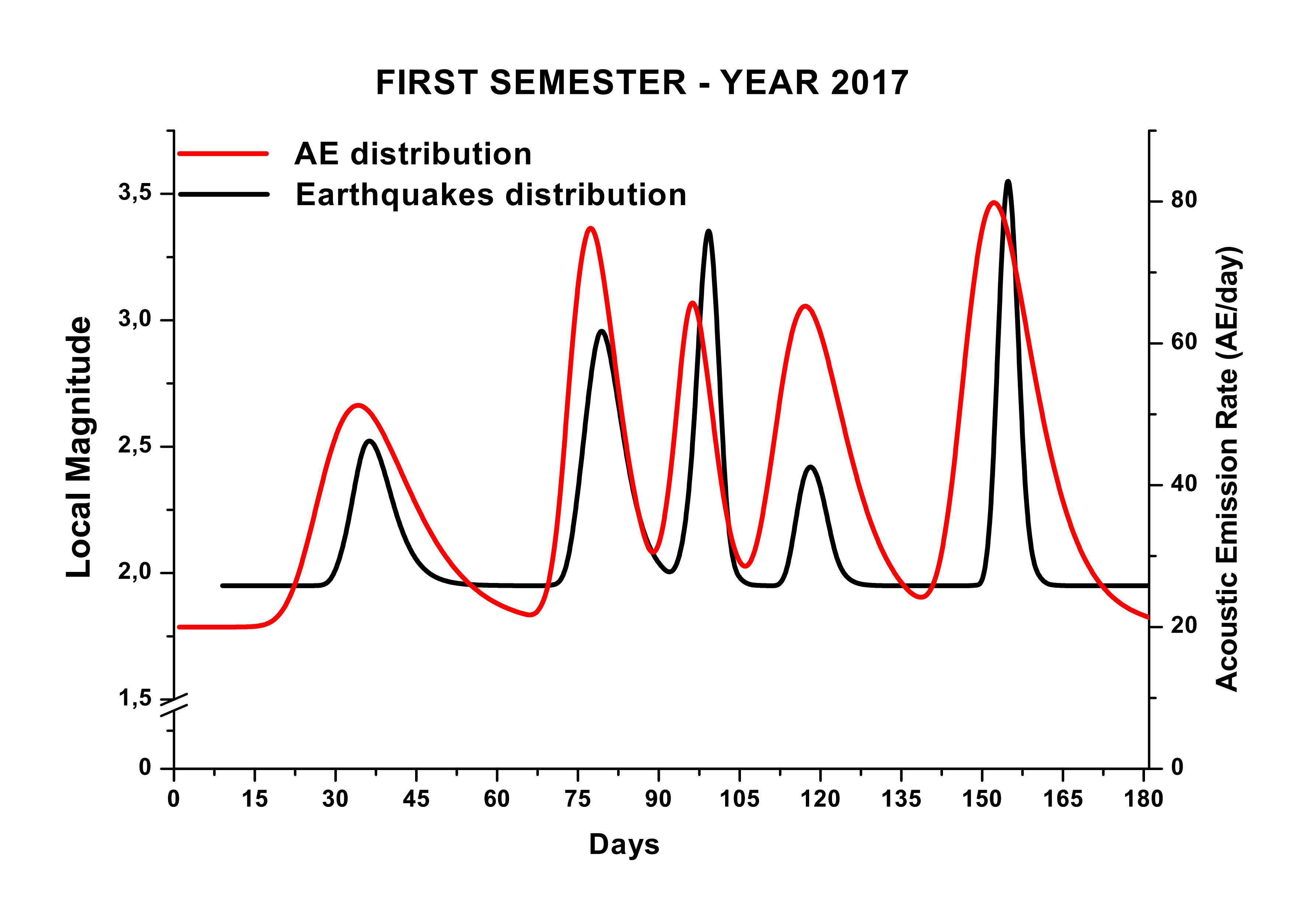
EME MULTI-MODAL ANALYSIS (First Sem. 2017)



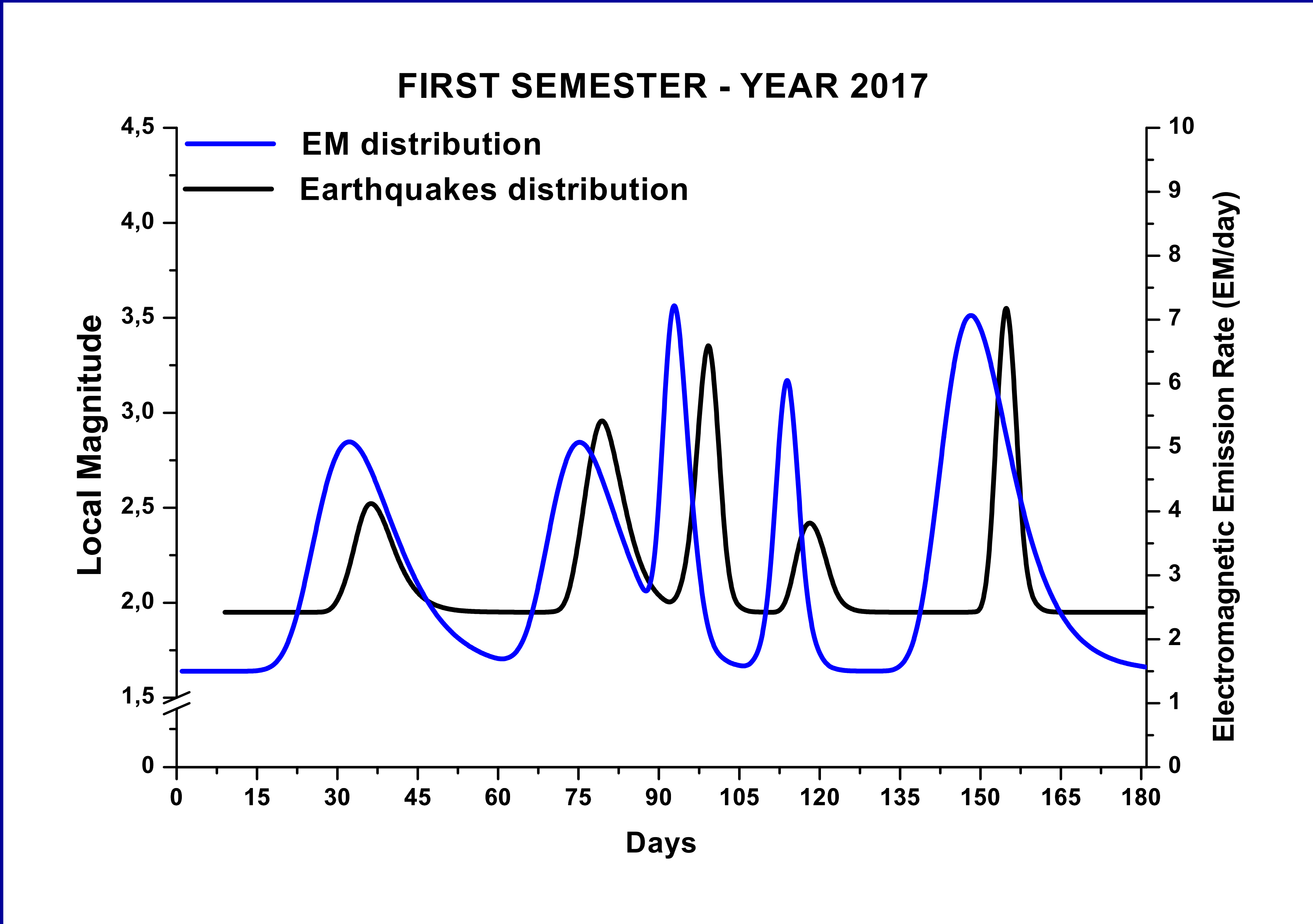
NE MULTI-MODAL ANALYSIS (First Sem. 2017)



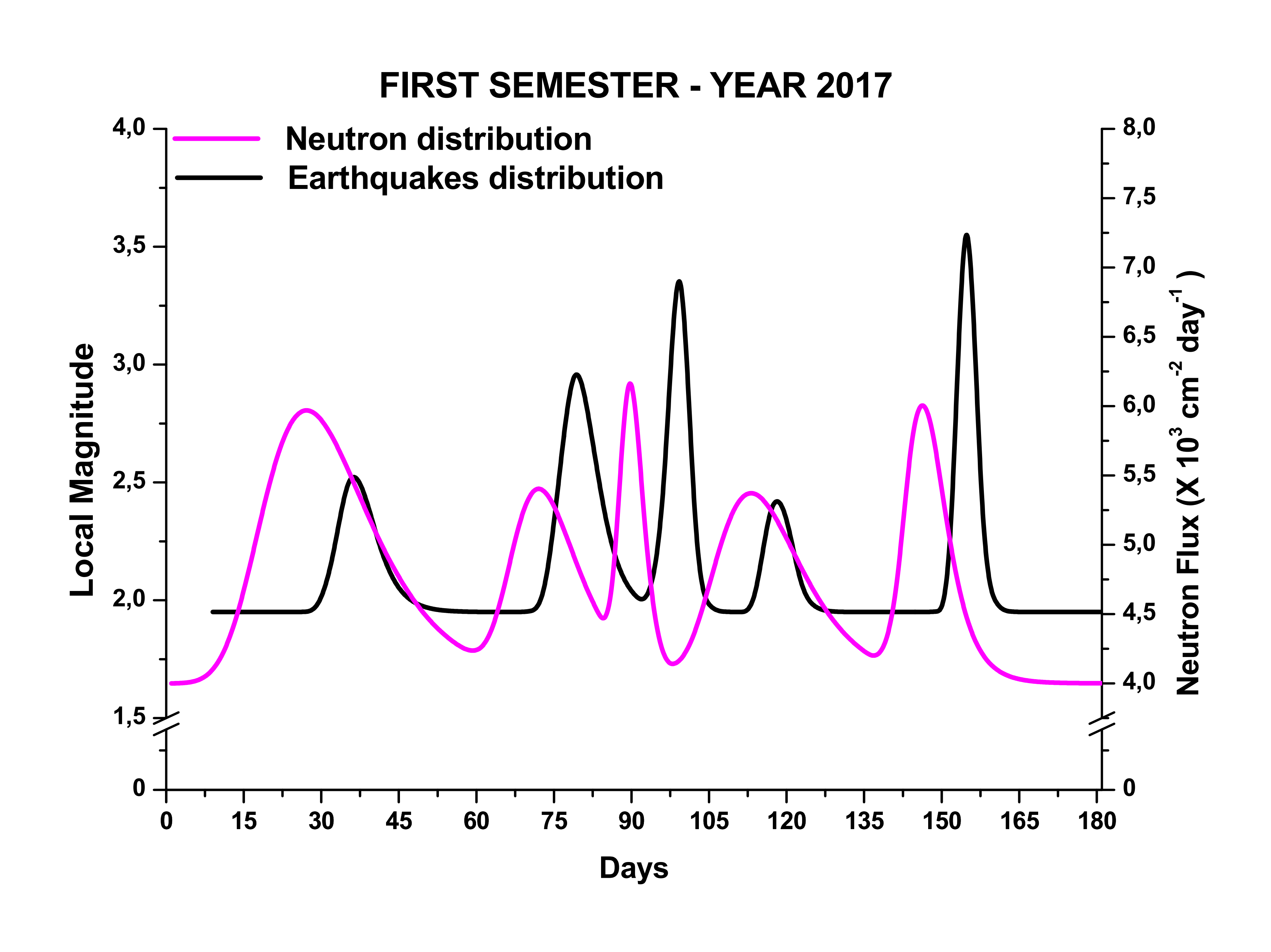
AE vs EARTHQUAKES (First Sem. 2017)



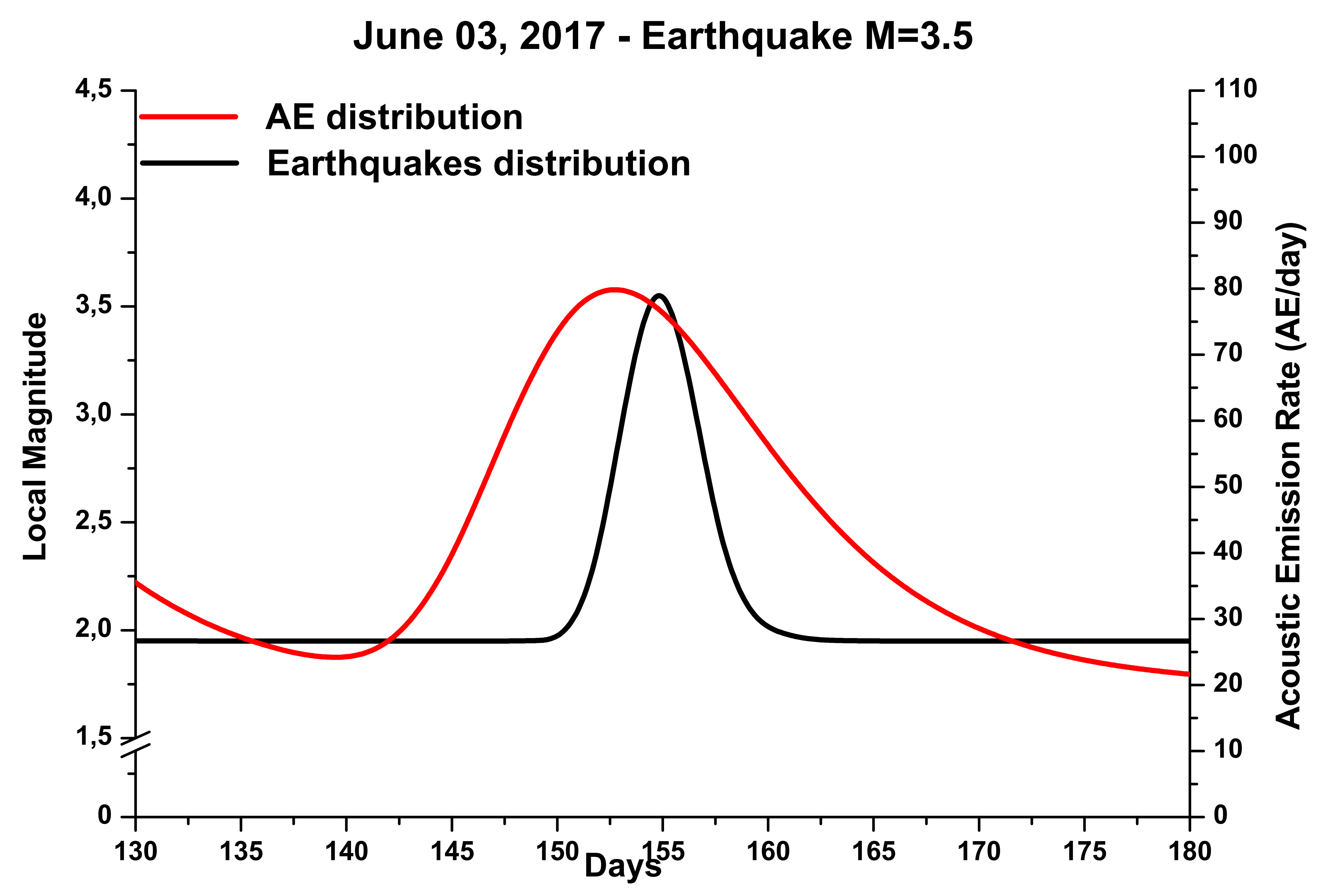
EME vs EARTHQUAKES (First Sem. 2017)

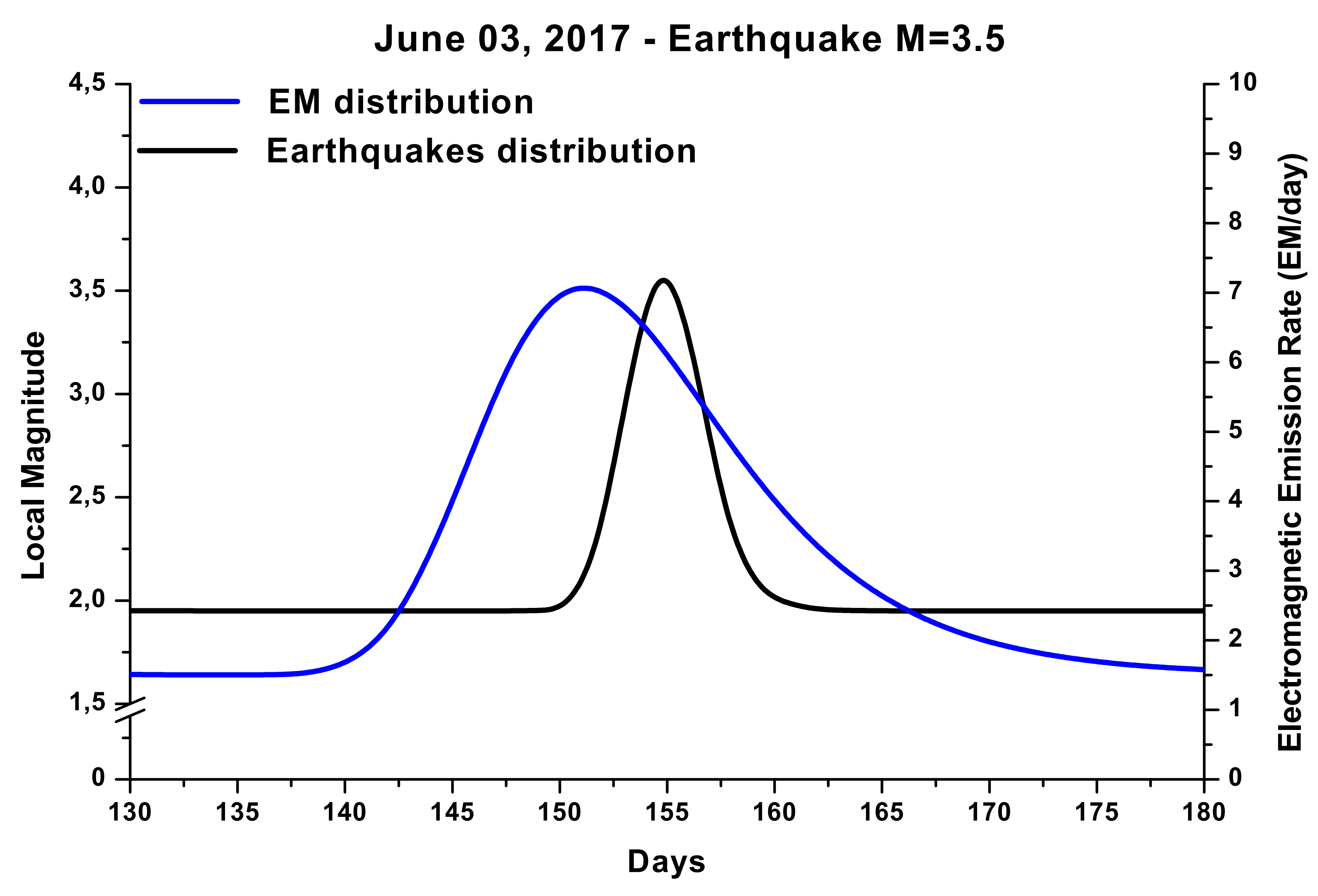


NE vs EARTHQUAKES (First Sem. 2017)

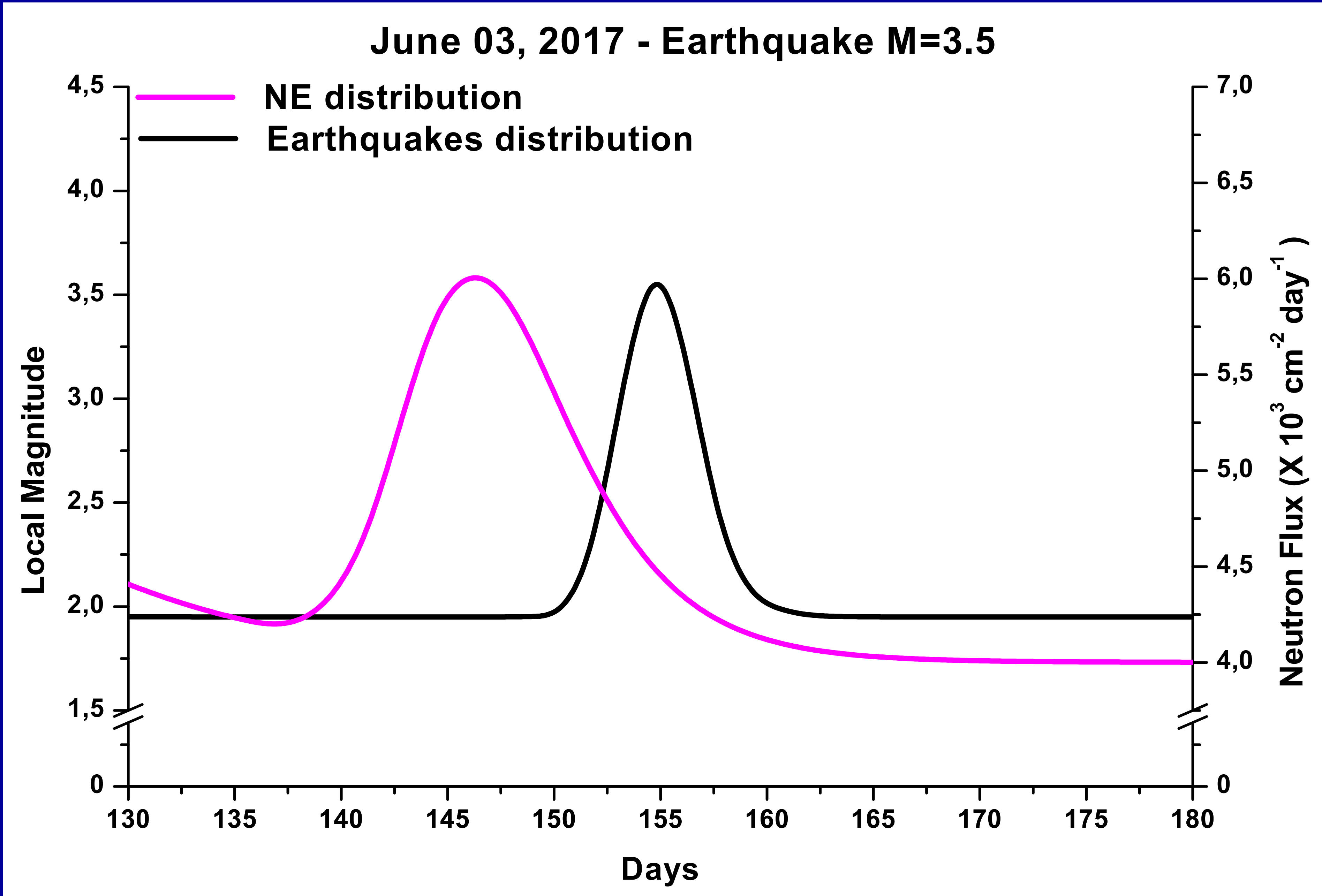


FRACTO-EMISSION CHRONOLOGICALLY ORDERED SHIFTING





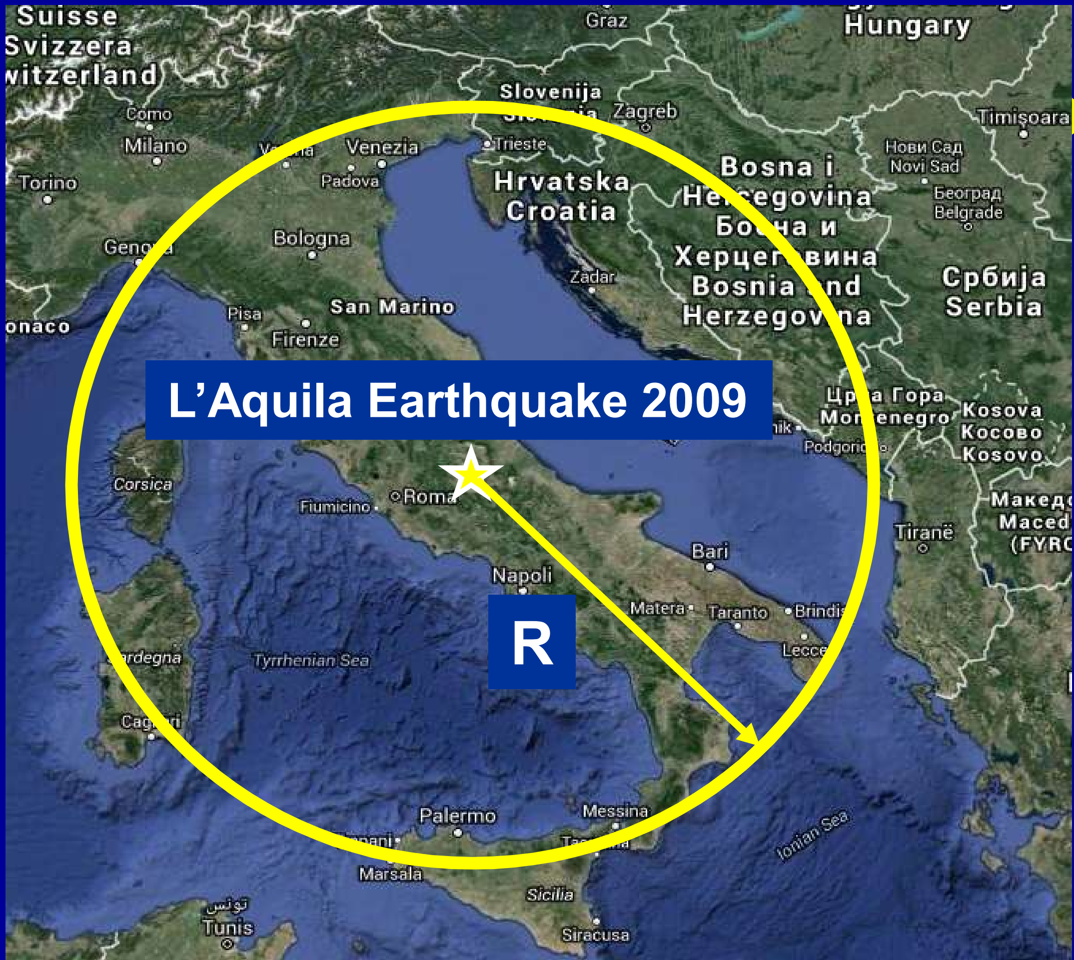
June 03, 2017 - Earthquake M=3.5
EM distribution
Earthquakes distribution
Local Magnitude
Electromagnetic Emission Rate (EM/day)
Days
4,5
4,0
3,5
3,0
2,5
2,0
1,5
0
10
9
8
7
6
5
4
3
2
1
0
130
135
140
145
150
155
160
165
170
175
180



June 03, 2017 - Earthquake M=3.5
NE distribution
Earthquakes distribution
Local Magnitude
Neutron Flux (X 10^3 cm^-2 day^-1)
Days
4,5
4,0
3,5
3,0
2,5
2,0
1,5
0
7,0
6,5
6,0
5,5
5,0
4,5
4,0
0
130
135
140
145
150
155
160
165
170
175
180

EARTHQUAKE PREPARATION ZONE

$$R = 10^{0.433M+0.60}\ \text{km}\ (*)$$

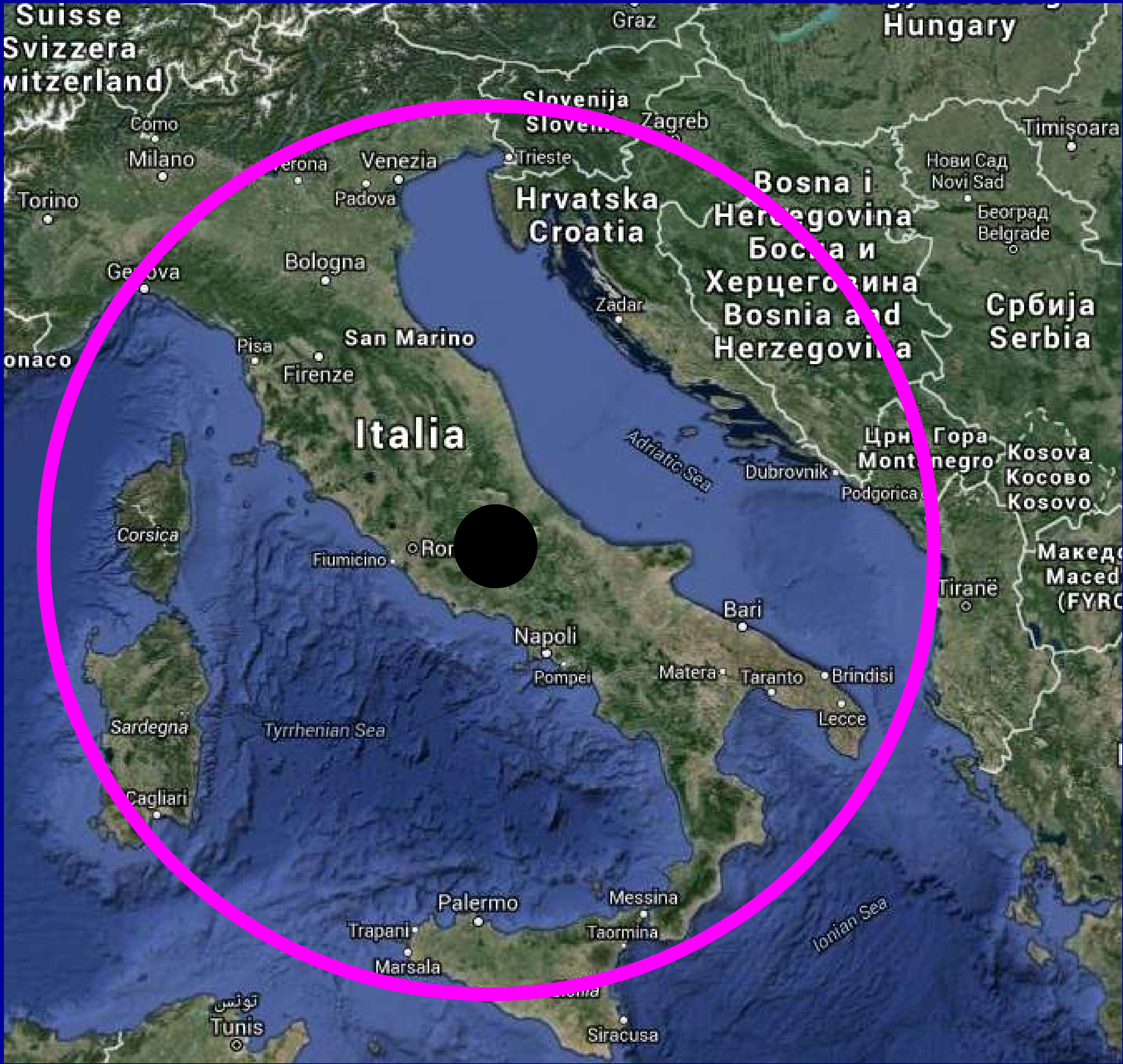


M = 3 ⟶ R ~ 100 Km

M = 6 ⟶ R ~ 1,000 Km

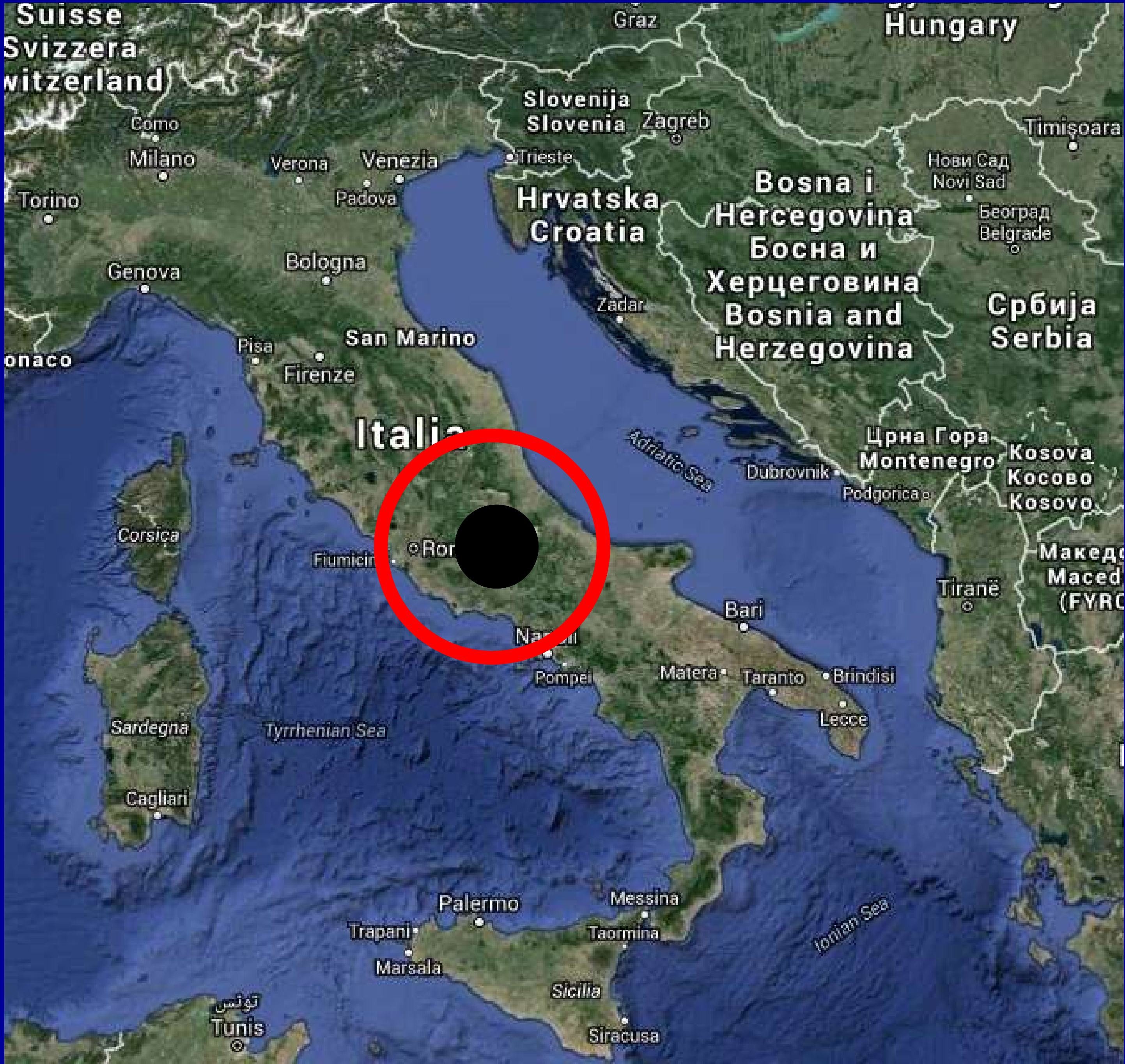
M = 9 ⟶ R ~ 10,000 Km

(*) Dobrovolsky I. P., Zubkov S. I., Miachkin V. I., (1979) "Estimation of the size of earthquake preparation zones", Pure and Applied Geophysics, Volume 117, Issue 5, pp 1025-1044.

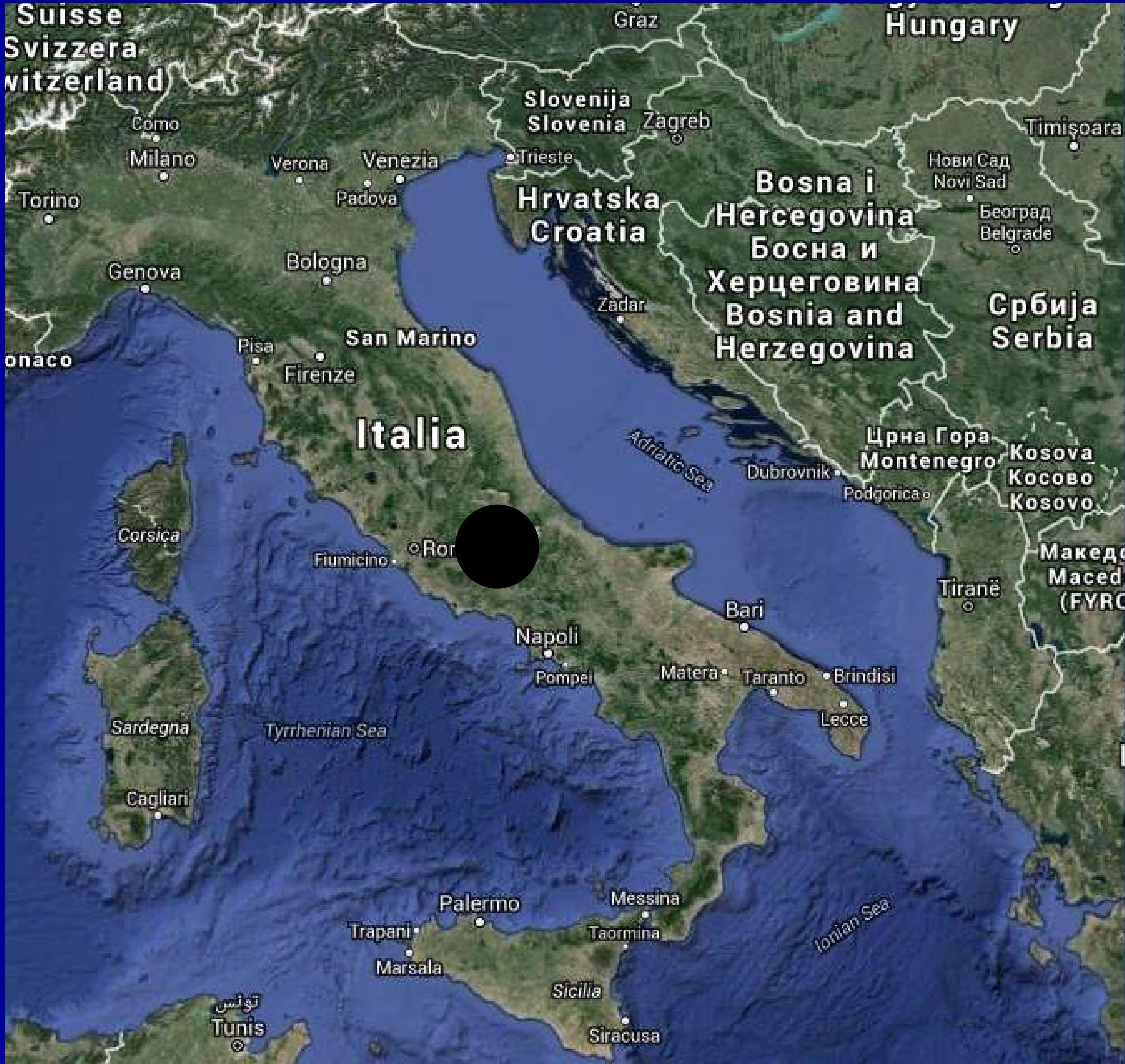


Equivalent crack size from 10^{-9} to 10^{-6} m

Equivalent crack size from 10^{-6} to 10^{-3} m

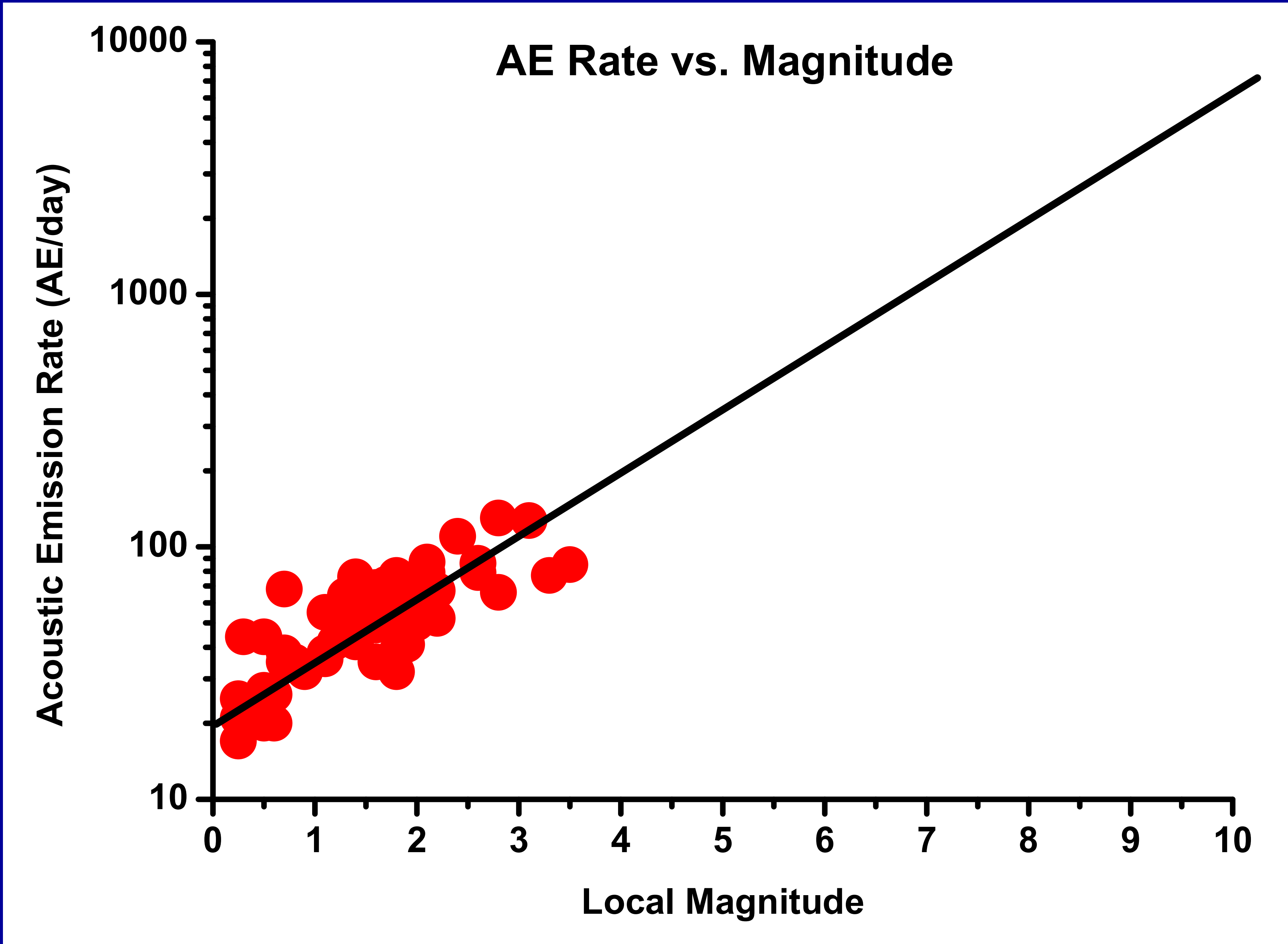


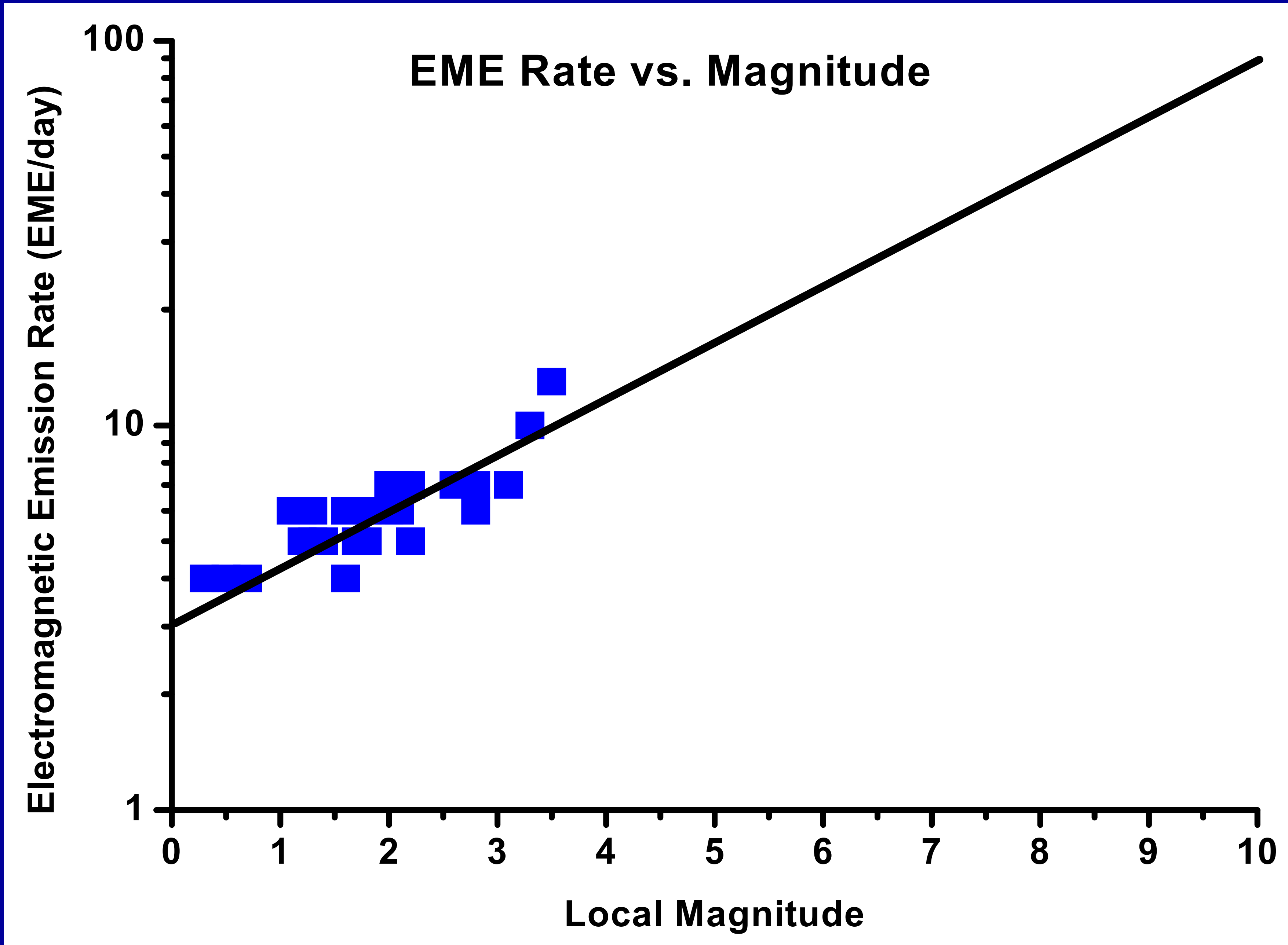
Equivalent crack size from 10^{-3} to 10^{0} m

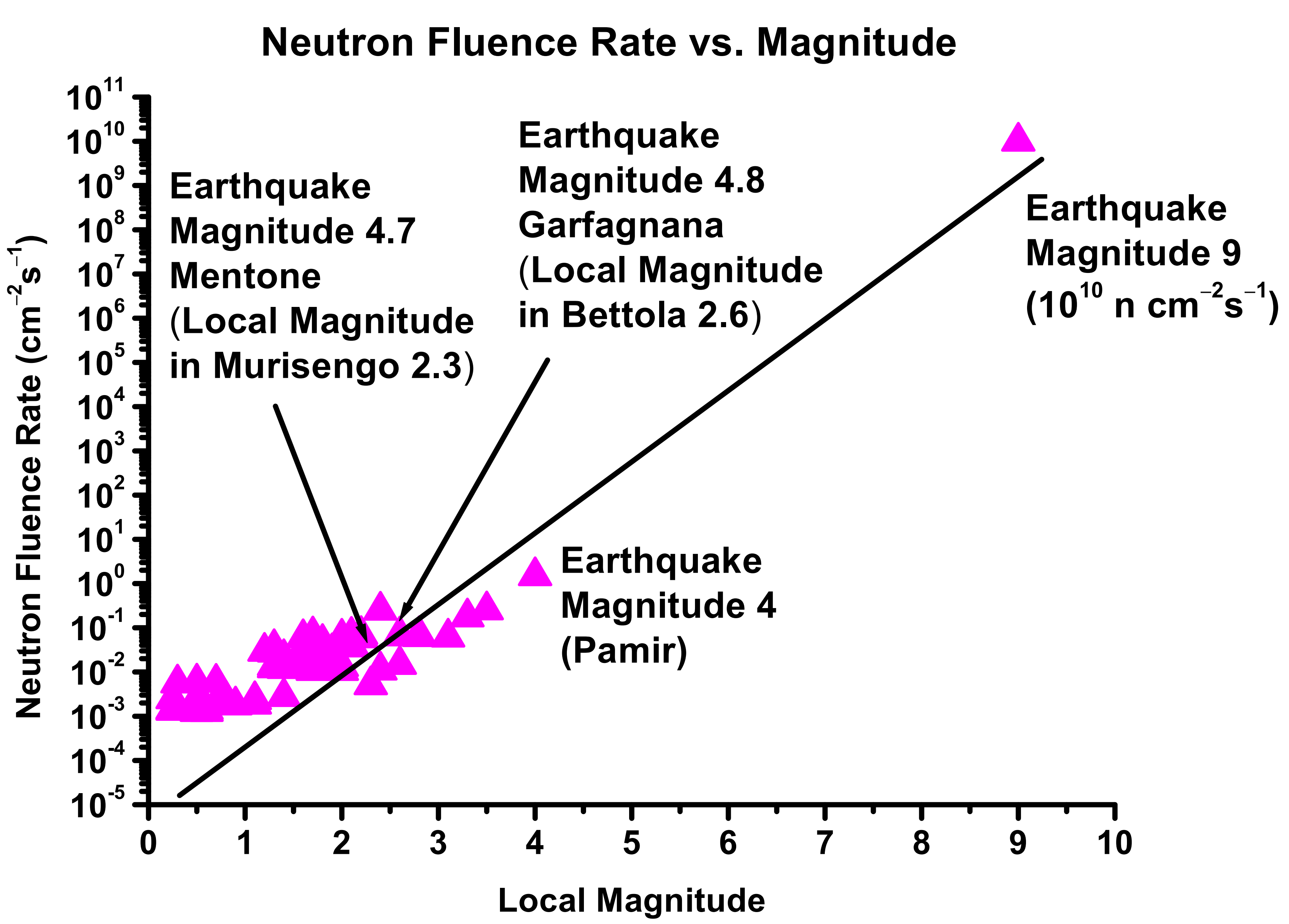


Equivalent crack size from 10^0 m to 10^3 m

FRACTO-EMISSION PEAK INTENSITY vs EARTHQUAKE LOCAL MAGNITUDE




EME Rate vs. Magnitude
Electromagnetic Emission Rate (EME/day)
Local Magnitude
100
10
1
0
1
2
3
4
5
6
7
8
9
10


Neutron Fluence Rate vs. Magnitude
Neutron Fluence Rate (cm^{-2}s^{-1})
Local Magnitude
Earthquake Magnitude 4.7 Mentone (Local Magnitude in Murisengo 2.3)
Earthquake Magnitude 4.8 Garfagnana (Local Magnitude in Bettola 2.6)
Earthquake Magnitude 9 (10^{10} n cm^{-2}s^{-1})
Earthquake Magnitude 4 (Pamir)
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0 1 2 3 4 5 6 7 8 9 10

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Fracto-emissions as seismic precursors

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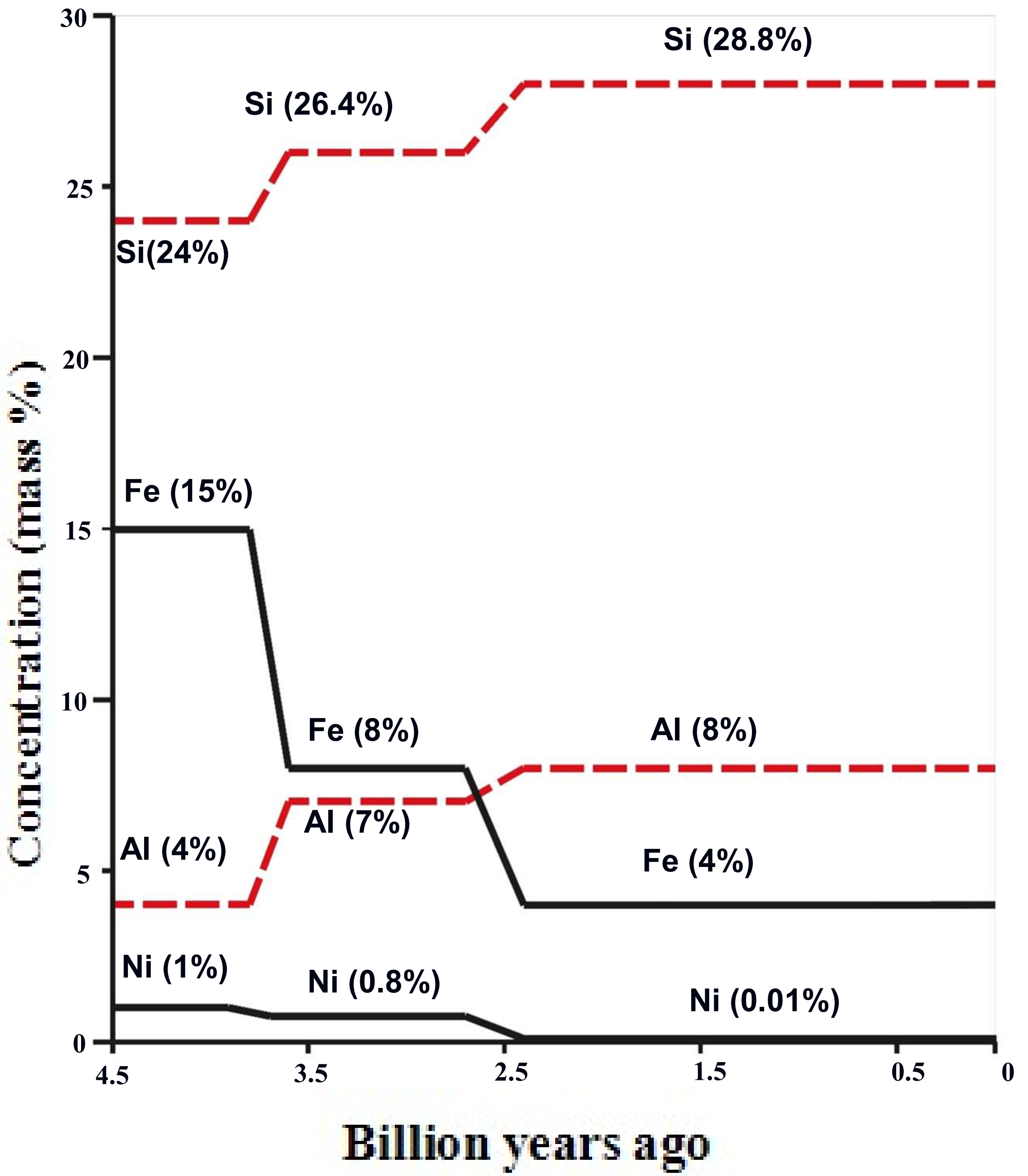
Earthquake precursors
Multi-modal statistics

A B S T R A C T

Three different forms of energy might be used as earthquake precursors for environmental protection against seismicity. At the tectonic scale, Acoustic Emission (AE) prevails, as well as Electro-Magnetic Emission (EME) at the intermediate scales, and Neutron Emission (NE) at the nano-scale. TeraHertz pressure waves are in fact produced at the last extremely small scale, and fracture experiments on natural rocks have recently demonstrated that these high-frequency waves are able to induce nuclear fission reactions with neutron and/or alpha particle emissions. Very important applications to earthquake precursors can be proposed. The authors present the results they are obtaining at a gypsum mine located in Northern Italy. In this mine, to avoid interference with human activities, the instrumental control units have been located at one hundred metres underground. The experimental results obtained from July 1st, 2013 to December 31, 2015 (five semesters) are analysed by means of a suitable multi-modal statistics. The experimental observations reveal a strong correlation between the three fracto-emission peaks (acoustic, electromagnetic, and neutron emissions) and the major earthquakes occurred in the surrounding areas.

CHEMICAL EVOLUTION
AT THE PLANETARY SCALE

IRON DEPLETION vs CARBON POLLUTION



Tectonic plate formation

(3.8 Billion years ago):
Fe (–7%) + Ni (–0.2%) =
=Al (+3%) + Si (+2.4%) + C (+1.8%)

Most severe tectonic activity

(2.5 Billion years ago):
Fe (–4%) + Ni (–0.8%) =
=Al (+1%) + Si (+2.4%) + C (+1.4%)

Conjecture about ferrous elements' transformations in the Earth Crust

(1) $Fe^{56}_{26} \rightarrow 2\,Al^{27}_{13} + 2n$

(2) $Fe^{56}_{26} \rightarrow Mg^{24}_{12} + Si^{28}_{14} + 4n$

(3) $Ni^{59}_{28} \rightarrow 2\,Si^{28}_{14} + 3n$

MAGNESIUM TRANSFORMATION INTO CARBON IN THE PRIMORDIAL ATMOSPHERE

The estimated Mg increase (~3.2%) is equivalent to the Carbon content in the primordial atmosphere:

$$Fe_{26}^{56} \rightarrow Mg_{12}^{24} + Si_{14}^{28} + 4n$$

$$Mg_{12}^{24} \rightarrow 2C_{6}^{12}$$

Assuming a mean density of the Earth Crust equal to 3.6 g/cm^3 and a thickness of ~60 km, the mass increase in Mg (~3.5×10^{21} kg), and therefore in C, implies a very high atmospheric pressure.

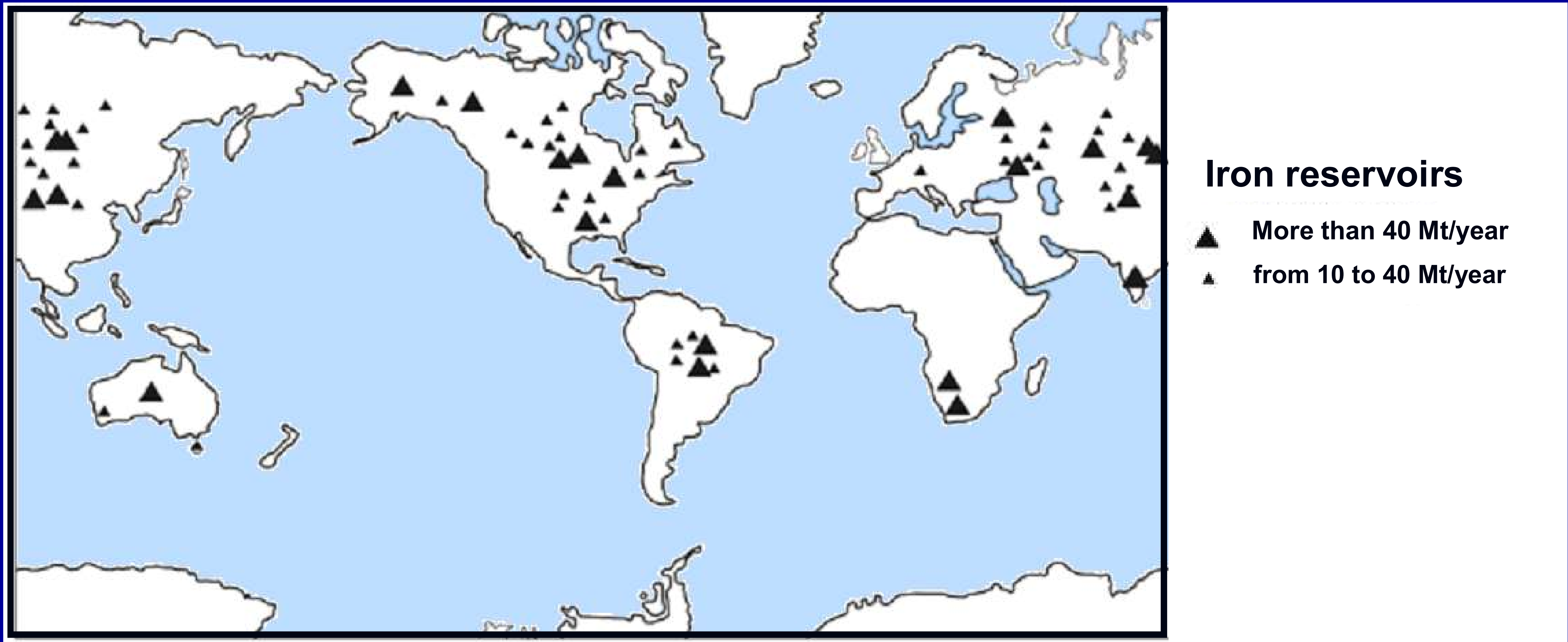
Primordial atmospheric pressure due to C increase = ~660 atm

⟷

Primordial atmospheric pressure reported by other authors = ~650 atm (Liu, 2004)

Liu, L., "The inception of the oceans and CO_2-atmosphere in the early history of the Earth". *Earth Planet. Sci. Lett.*, 227, 179–184 (2004)

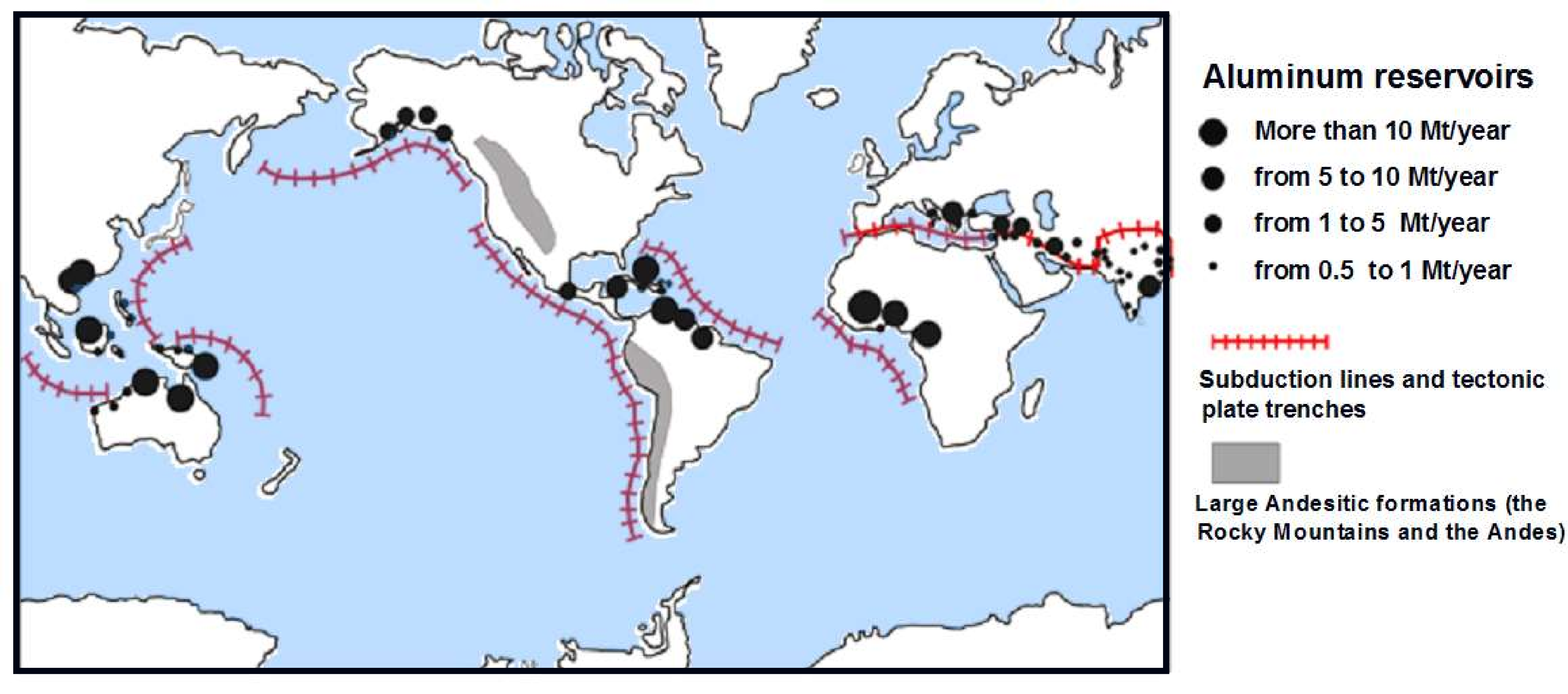
Localization of iron mines



(*) World Iron Ore producers. Available at http://www.mapsofworld.com/minerals/world-iron-ore-producers.html.

(**) World Mineral Resources Map. Available at http://www.mapsofworld.com/world-mineral-map.html.

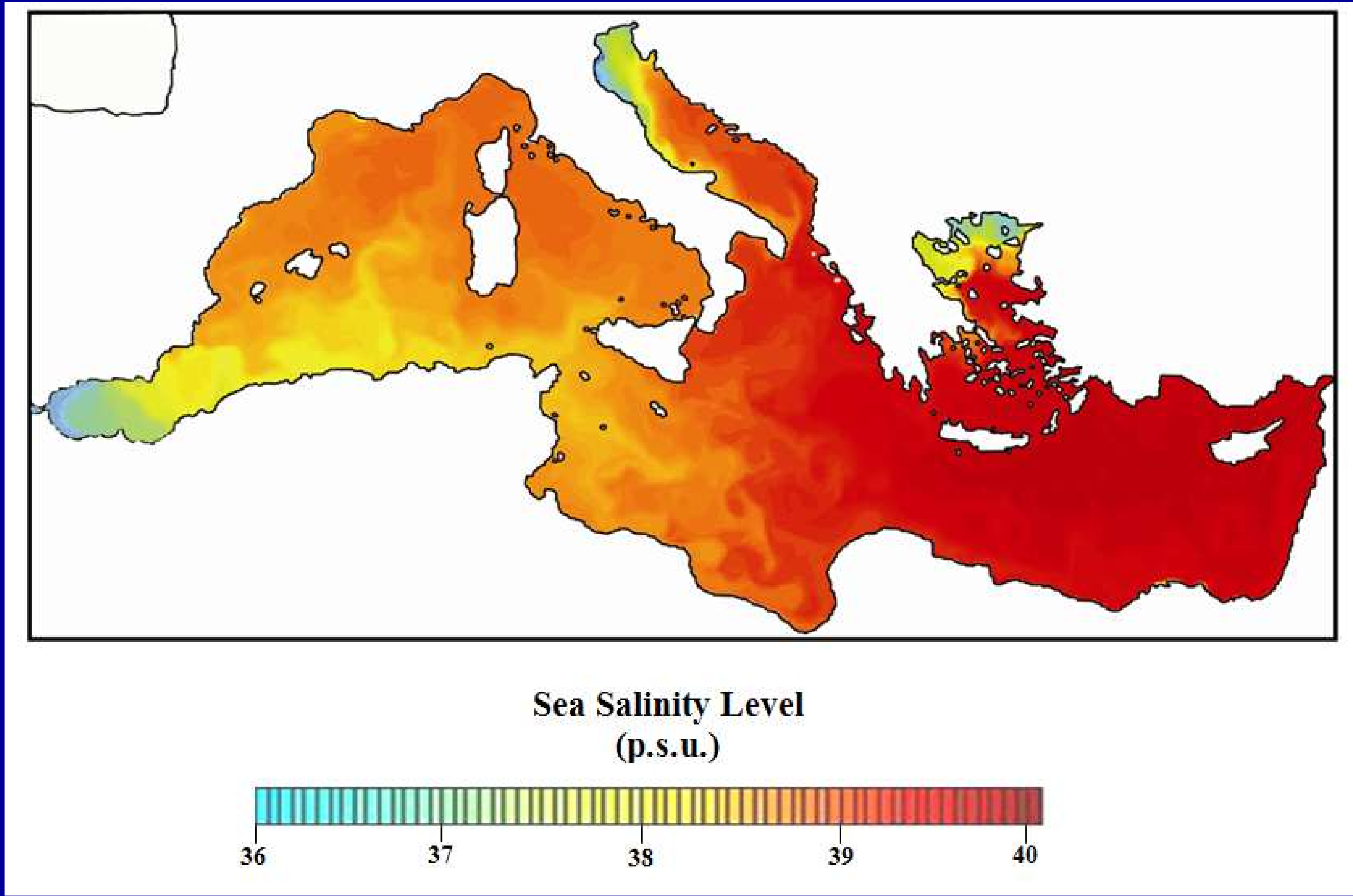
Localization of Aluminum mines



(*) World Iron Ore producers. Available at http://www.mapsofworld.com/minerals/world-iron-ore-producers.html.

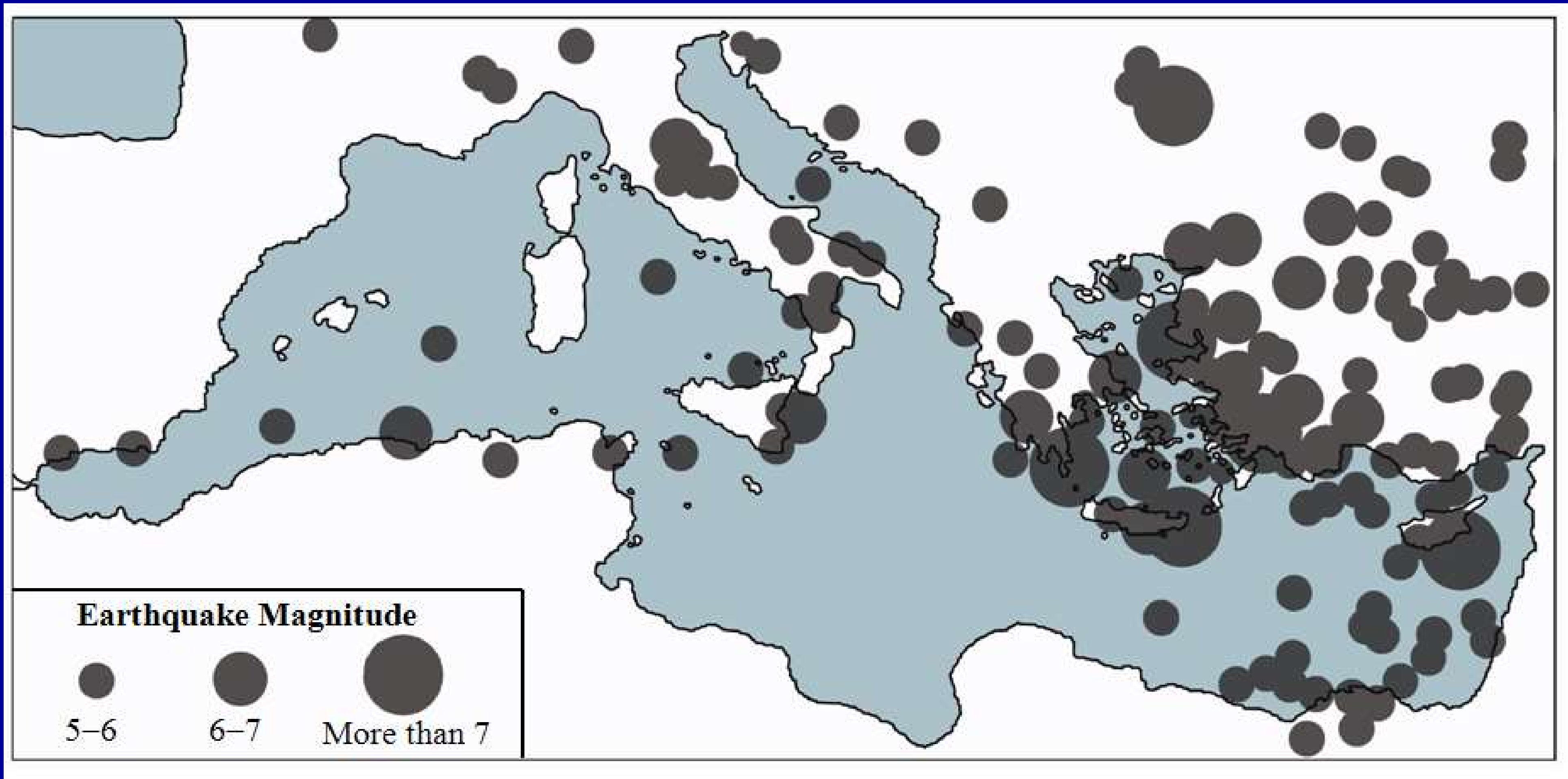
(**) World Mineral Resources Map. Available at http://www.mapsofworld.com/world-mineral-map.html.

Salinity level in the Mediterranean Sea



Map of the salinity level in the Mediterranean Sea expressed in p.s.u. The Mediterranean basin is characterized by the highest sea salinity level in the World.

Map of the major earthquakes in the years 1995-2010



Nickel Depletion: $Ni^{59}_{28} \rightarrow Na^{23}_{11} + Cl^{35}_{17} + 1n$

HIERARCHY OF PIEZONUCLEAR FISSION REACTIONS

Two piezonuclear fission reaction jumps typical of the Earth Planet:

$Fe_{26}, Co_{27}, Ni_{28}$ (NI-FE)

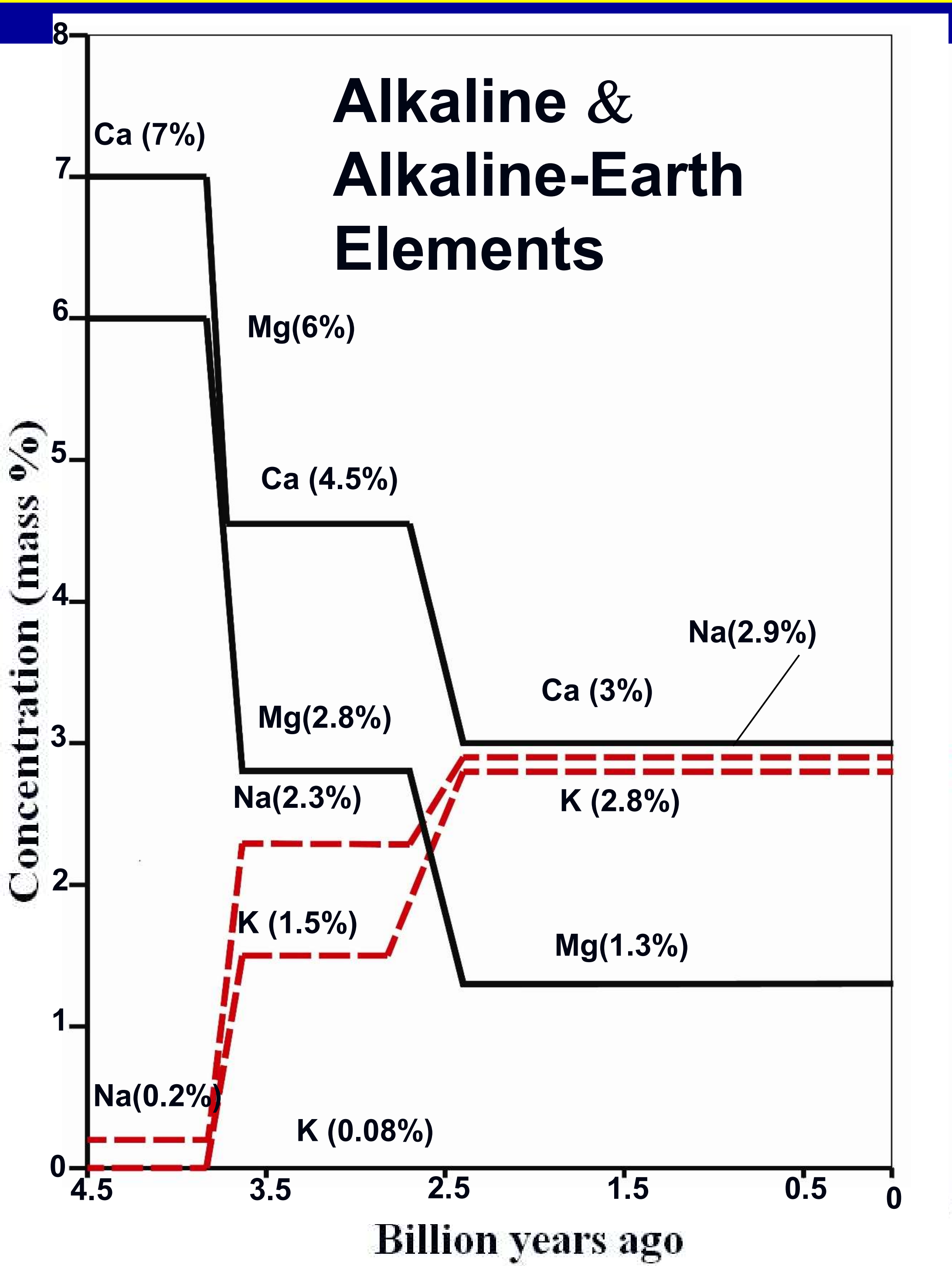
$\downarrow$

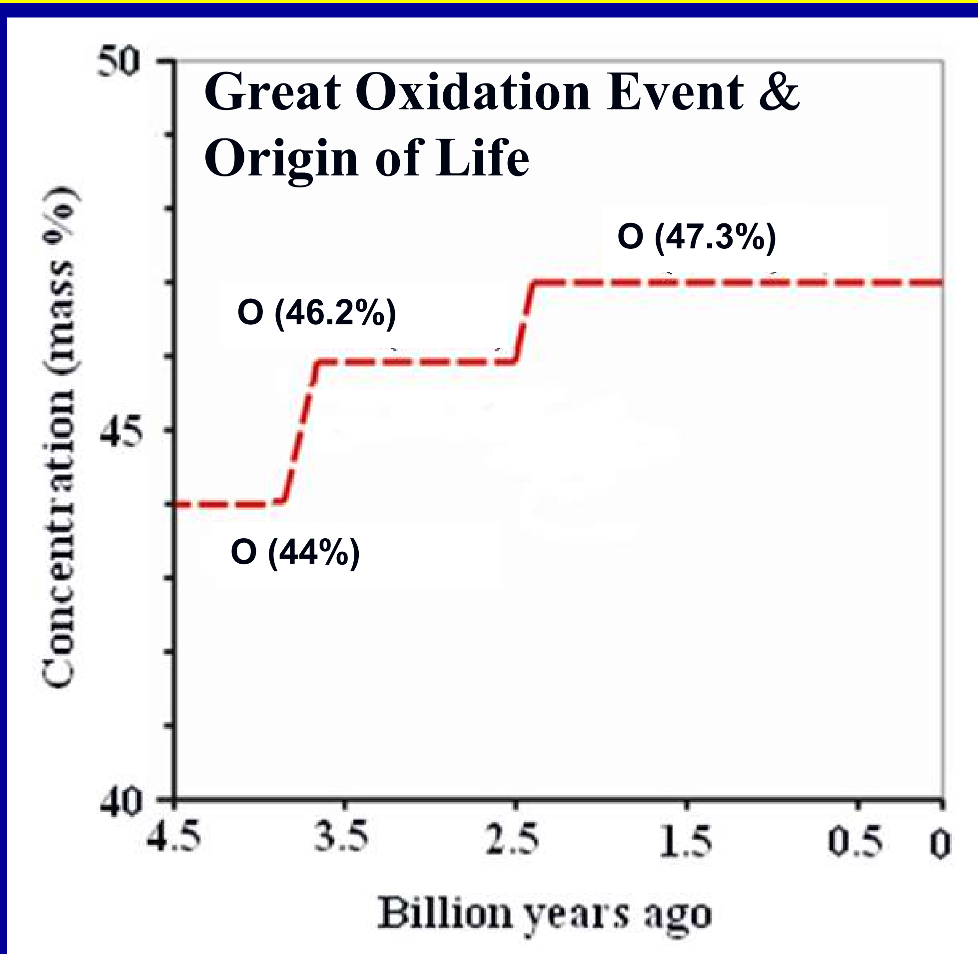
$Mg_{12}, Al_{13}, Si_{14}$ (SI-MA, SI-AL)

$\downarrow$

C_{6}, N_{7}, O_{8} (Atmosphere)

CALCIUM DEPLETION vs OCEAN FORMATION





3.8 Billion years ago:
Ca (–2.5%) + Mg(–3.2%) =
= K (+1.4%) + Na (+2.1%) + O (+2.2%)

2.5 Billion years ago:
Ca (–1.5%) + Mg(–1.5%) =
=K (+1.3%) + Na (+0.6%) + O (+1.1%)

Conjecture about Alkaline-Earth elements' transformations

(1) $Mg_{12}^{24} \rightarrow Na_{11}^{23} + H_1^1$

(2) $Mg_{12}^{24} \rightarrow O_8^{16} + 2H_1^1 + He_2^4 + 2n$

(3) $Ca_{20}^{40} \rightarrow K_{19}^{39} + H_1^1$

(4) $Ca_{20}^{40} \rightarrow 2O_8^{16} + 4H_1^1 + 4n$

Conjecture about Alkaline-Earth elements' transformations

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(3) $Ca_{20}^{40} \rightarrow K_{19}^{39} + H_1^1$

(4) $Ca_{20}^{40} \rightarrow 2O_8^{16} + 4H_1^1 + 4n$

Ocean Formation

<u>Calcium depletion</u> and ocean formation

Global decrease in Ca (–4.0%) is counterbalanced by an increase in K (+2.7%) and in H_2O (+1.3%).

$$Ca_{20}^{40} \rightarrow K_{19}^{39} + H_1^1$$

$$Ca_{20}^{40} \rightarrow 2O_8^{16} + 4H_1^1 + 4n$$

Assuming a mean density of the Earth Crust equal to 3.6 g/cm3 and a thickness of ~60 km, the partial mass decrease in Ca due to the second reaction is about 1.40 $\times 10^{21}$ kg.

Considering a global ocean surface of 3.61 $\times 10^{14}$ m^2, and an average depth of 3950 m, we obtain a mass of water of about 1.35 $\times 10^{21}$ kg

Partial decrease in Ca 1.40 $\times 10^{21}$ kg ⟷ **Mass of H_2O in the oceans today 1.35 $\times 10^{21}$ kg**

strain
An International Journal for Experimental Mechanics

Geomechanical and Geochemical Evidence of Piezonuclear Fission Reactions in the Earth's Crust

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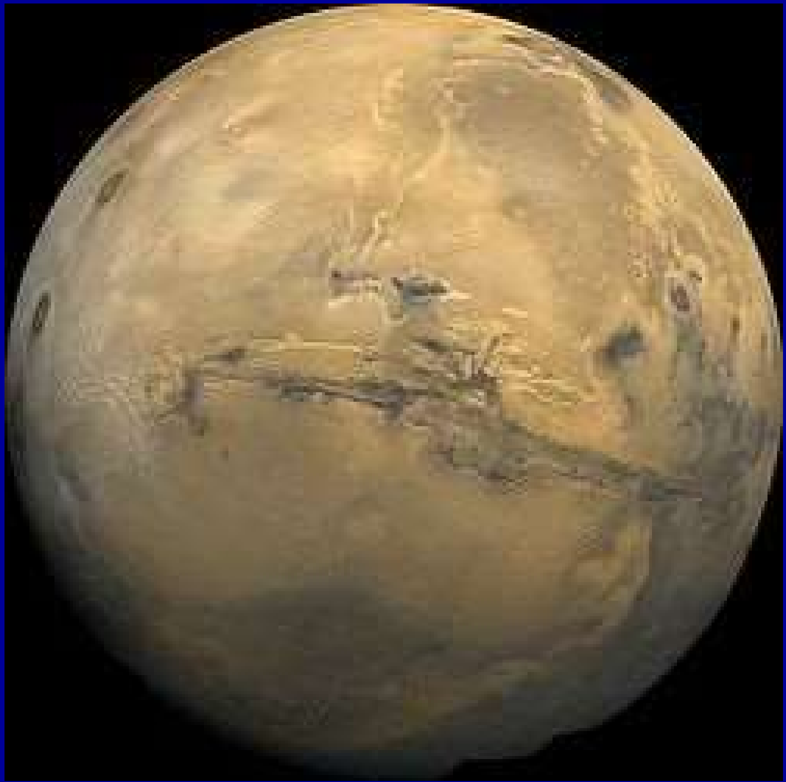
ABSTRACT: Piezonuclear reactions, which occur in inert and non-radioactive elements, are induced by high pressure and, in particular, by brittle fracture phenomena in solids under compression. These low-energy reactions generally take place in nuclei with an atomic weight that is lower or equal to that of iron (Fe). The experimental evidence, obtained from repeatable measurements of neutron emissions [*Strain* 45, 2009, 332; *Strain* (in press); Phys. Lett. A. 373, 2009, 4158], can be also recognised considering the anomalous chemical balances of the major events that have affected the Earth's crust, oceans and atmosphere, over the last 4 billion years. These anomalies include (i) abrupt variations in the most abundant elements in correspondence with the formation of tectonic plates; (ii) the 'Great Oxidation Event' (2.7–2.4 billion years ago), with a sharp increase in atmospheric oxygen and the subsequent origin of life; (iii) the current climate acceleration partially because of 'carbon pollution'. Natural piezonuclear reactions are induced by fault sliding and plate subduction phenomena.

KEY WORDS: *carbon pollution, element evolution, Great Oxidation Event, neutron emissions, piezonuclear reactions, plate tectonics, rocks crushing*

CHEMICAL EVOLUTION
IN THE PLANETS OF SOLAR SYSTEM

MARS: THREE INDEPENDENT INVESTIGATIONS

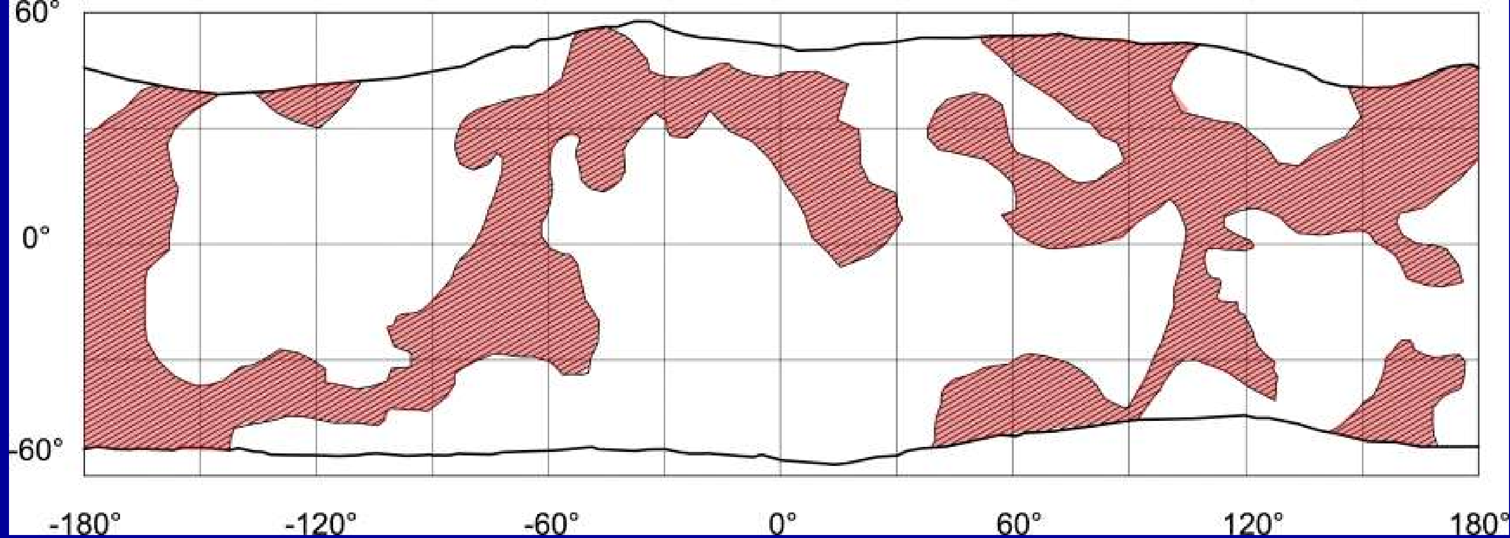


Mars Odissey, Nasa 2001
Mars Global Surveyor, Nasa 1996

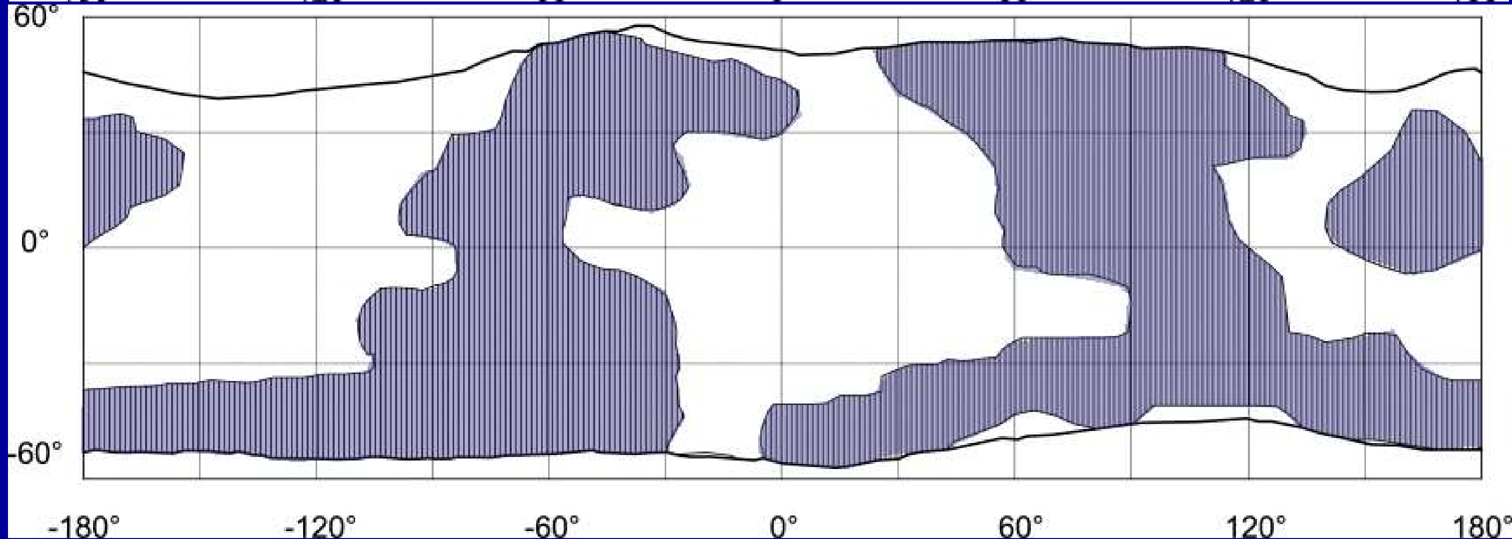
- Seismicity
- Neutron Emissions
- Elemental Abundance

1. Knapmeyer M. et al. "Working Models for Spatial Distribution and Level of Mars Seismicity" *J. of Geophys. Res.*, 111, E11006, (2006).
2. Hahn, B., McLennan, S., "Gamma-Ray Spectometer Elemental Abundance Correlation with Martian Surface Age: Implication for Martian Crustal Evolution". *Lunar and Planet. Sci.* 37,1904 (2006).
3. Mitrofanov, I. et al., "Maps of Subsurface Hydrogen from the High Energy Neutron Detector, Mars Odyssey", *Science*, 297, 78-81, (2002).

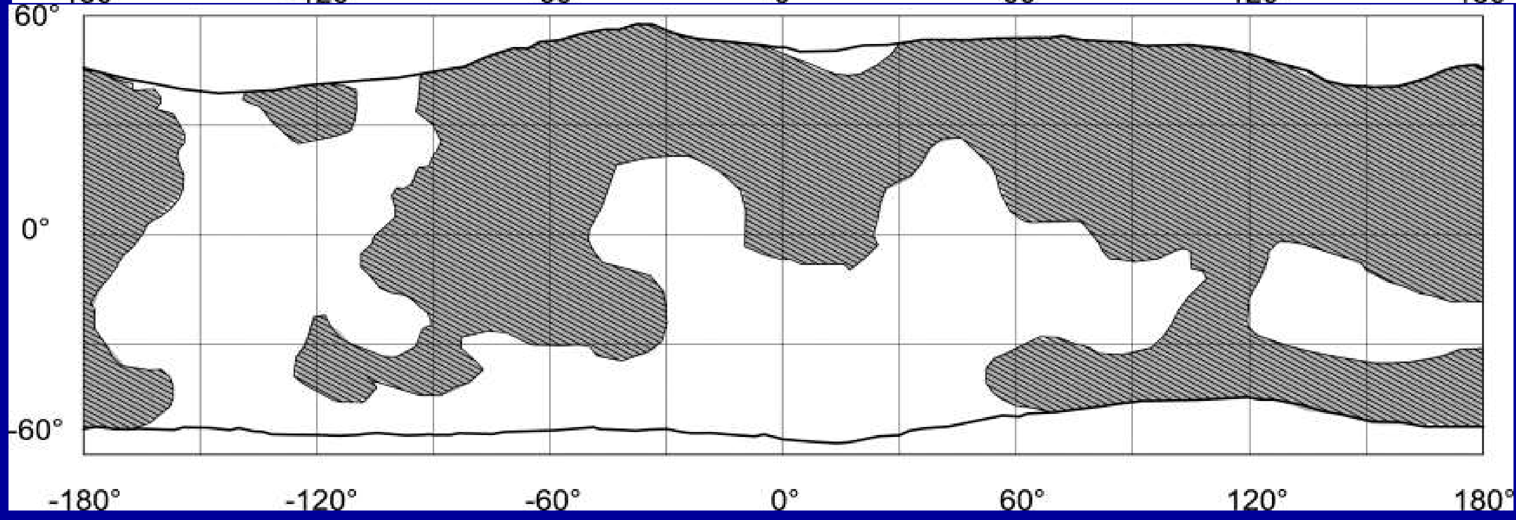
Faults



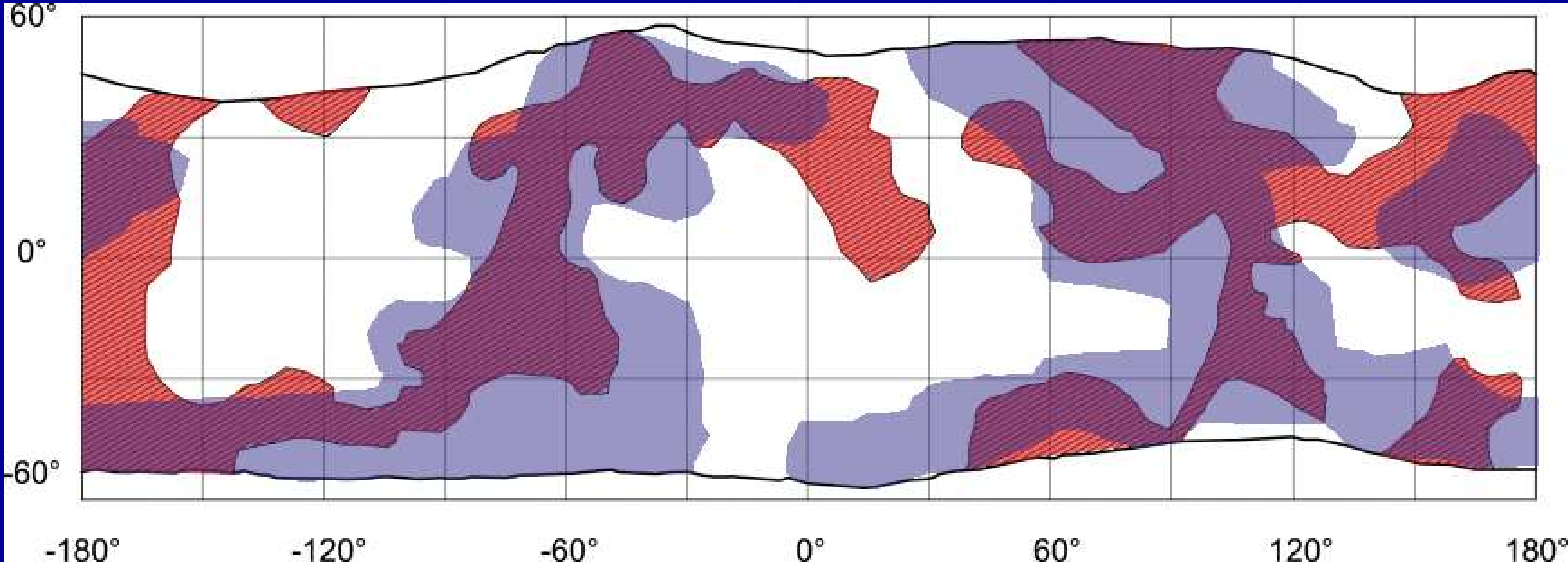
Neutrons (> 0.18 cps)



Iron (≥ 15%)



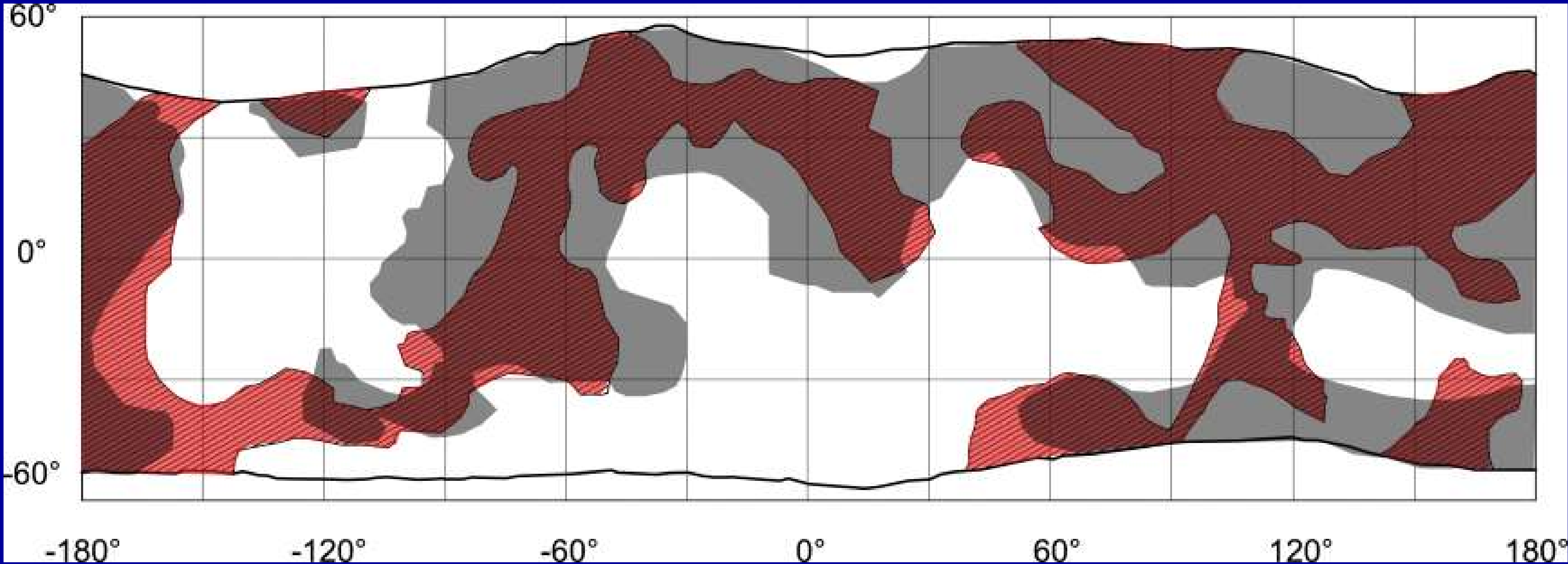
Faults vs Neutrons

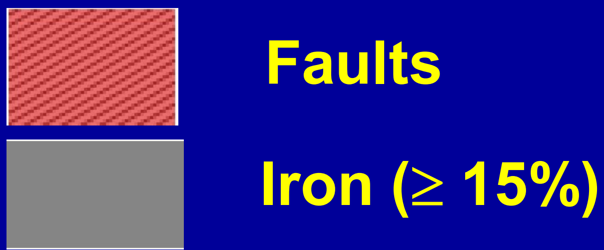


Faults

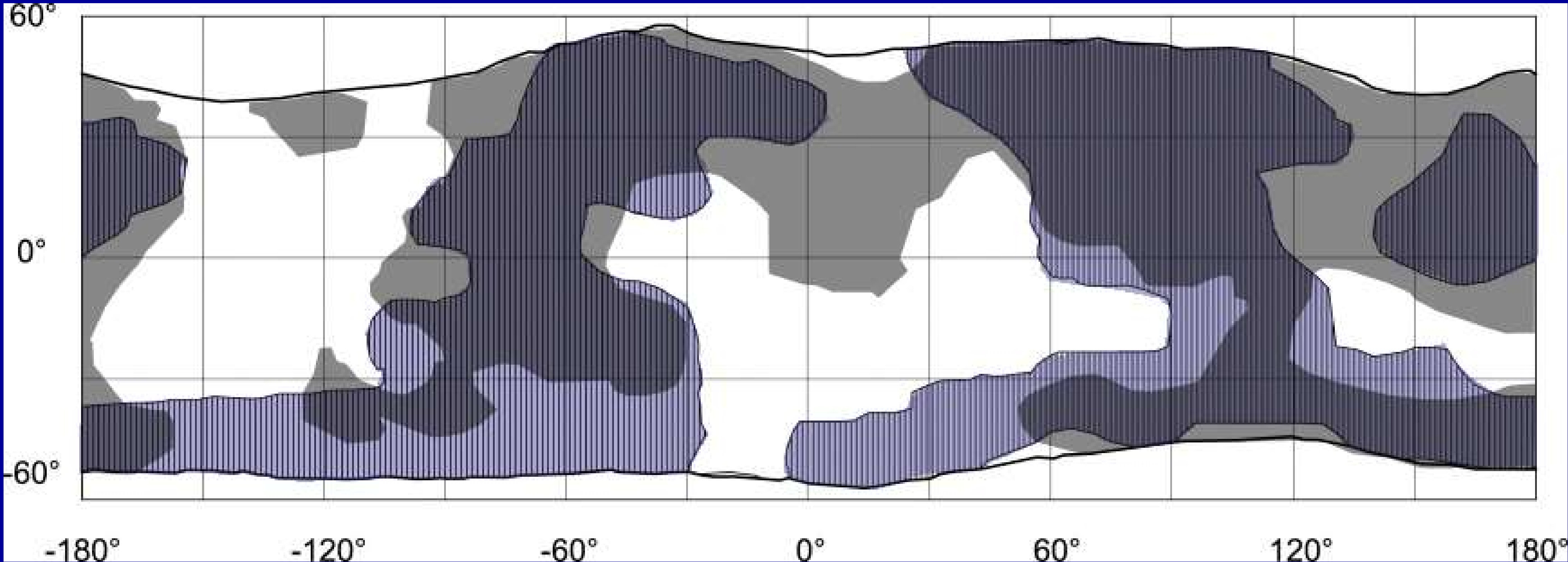
Neutrons (> 0.18 cps)

Faults vs Iron





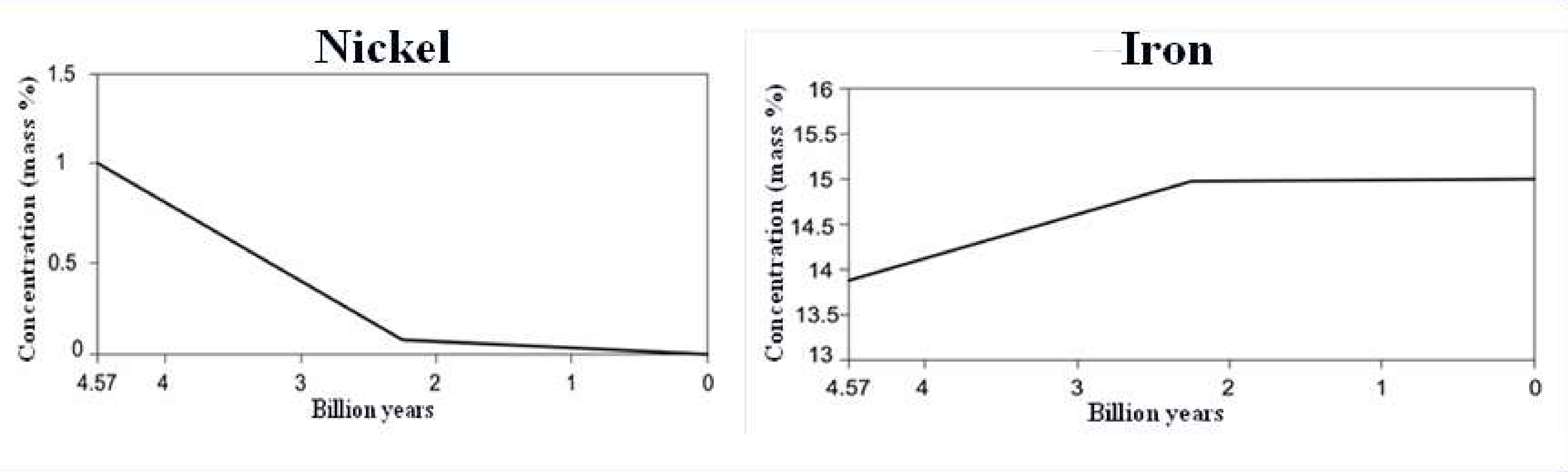
Iron vs Neutrons



Iron (≥ 15%)

Neutrons (> 0.18 cps)

Element evolution: Ni-Fe transformation



Ni decrease ~ Fe increase ~ 1.0%

$$Ni_{28}^{59} \rightarrow Fe_{26}^{56} + 2H_1^1 + 1n$$

1.Hahn B. C., McLennan S. M. (2006) Gamma-Ray Spectometer Elemental Abundance Correlation with Martian Surface Age: Implication for Martian Crustal Evolution. *Lunar and Planetary Science* XXXVII.