Nanomechanics instabilities and TeraHertz vibrations: From geochemical evolution to fracto-emission seismic precursors

Alberto. Carpinteri

Politecnico di Torino, Department of Structural, Geotechnical and Building Engineering
Corso Duca degli Abruzzi 24, 10129 Torino, Italy

e-mail: alberto.carpinteri@polito.it

Abstract. 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. The same phenomenon appears to have occurred in several different situations and to explain puzzles related to the history of our planet, like the ocean formation or the primordial carbon pollution. In addition, 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 meters underground. The experimental results obtained from July 1st, 2013 to December 31, 2015 (five semesters) are analyzed by means of a suitable multi-modal statistics. The experimental observations reveal a strong correlation between the three fracto-emission peaks (acoustic, electromagnetic, neutron) and the major earthquakes occurring in the closest areas.

Keywords: TeraHertz pressure waves, Fracto-emissions, Chemical evolution, Earthquake precursors, Multi-modal statistics

Introduction

Solids that break in a brittle way are subjected to a rapid release of energy involving the generation of pressure waves that travel at a characteristic speed with an order of magnitude of 10^3 metre/second. On the other hand, the wavelength of pressure waves emitted by forming or propagating cracks appears to be of the same order of magnitude of crack size or crack advancement length. The wavelength can not therefore exceed the maximum size of the body in which the crack is contained and may vary from the nanometre scale (10^{-9} metres), for defects in crystal lattices such as vacancies and dislocations, up to the kilometre, in the case of Earth's Crust faults (Figure 1).

Considering the very important case of earthquakes, it is possible to observe that, as fracture at the nanoscale (10^{-9} metres) emits pressure waves at the frequency scale of TeraHertz (10^{12} Hertz), so fracture at the microscale (10^{-6} metres) emits pressure waves at the frequency scale of GigaHertz (10^9 Hertz), at the scale of millimetre emits pressure waves at the scale of MegaHertz (10^6 Hertz), at the scale of metre emits pressure waves at the scale of kiloHertz (10^3 Hertz), and eventually faults at the kilometre scale emit pressure waves at the scale of the simple Hertz, which is the typical and most likely frequency of seismic oscillations (Figure 1). The animals with sensitive hearing in the ultrasonic field (frequency > 20 kiloHertz) "feel" the earthquake up to one day in advance, when the active cracks are still below the metre scale. Ultrasounds are in fact a well-known seismic precursor. With frequencies between Mega- and GigaHertz, and therefore cracks between the micron and the millimetre scale, pressure waves can generate electromagnetic waves of the same frequency, which turn out to be even a more advanced seismic precursor (up to a few days before). When pressure waves show frequencies between Giga- and TeraHertz, and then with cracks below the micron scale, we are witnessing a phenomenon partially unexpected: pressure waves resonate with the crystal lattices and, through a complex cascade of events (acceleration of electrons, bremsstrahlung gamma radiation, photo-fission, etc.), may produce nuclear fission reactions. It can be shown experimentally how such fission reactions can emit neutrons like in the well-known case of uranium-235 but without gamma radiation and radioactive wastes. Note that the Debye frequency, i.e., the fundamental frequency of free vibration of crystal lattices, is around the TeraHertz, and this is not a coincidence, since it is simply due to the fact that the inter-atomic distance is just around the nanometre, as indeed the minimum size of the lattice defects. As the chain reactions are sustained by thermal neutrons in a nuclear power plant, so the piezonuclear reactions are triggered by pressure waves that have a frequency close to the resonance frequency of the crystal lattice and an energy close to that of thermal neutrons. Neutrons therefore appear to be as the most advanced earthquake precursor (up to three weeks before).

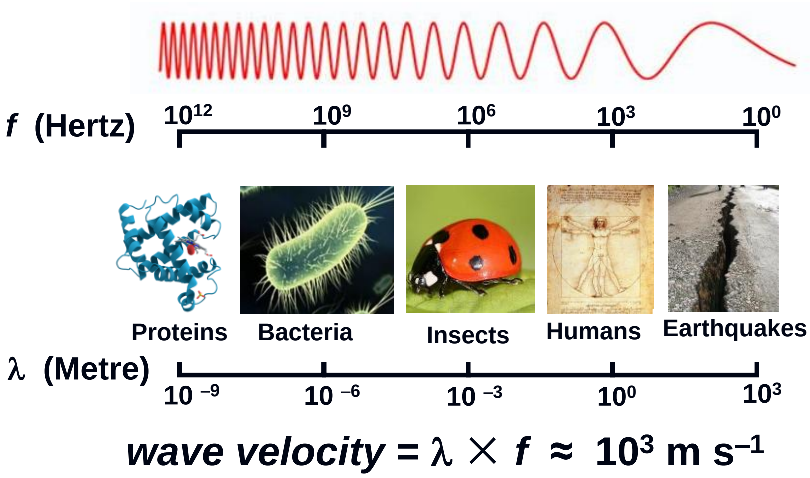

Figure 1: Correlation between wavelength (forming crack) scale and frequency scale by assuming a constant pressure wave velocity.

Chemical evolution of our planet and its reproduction in the fracture mechanics laboratory

The piezonuclear fission reactions appear to be induced by pressure waves at very high frequencies (TeraHertz). They are often accompanied and revealed by the emission of neutrons and/or alpha particles. However, gamma rays and radioactive wastes appear to be absent in the experiments. Ultrasonic pressure waves may in turn be produced by the most common mechanical instabilities, such as fracture in solids and turbulence in fluids. Both are hierarchical, multi-fractal, and dissipative phenomena, where cracks and vortexes, respectively, are present at the different scales.

After the early experiments conducted at the National Research Council of Italy (CNR), soliciting with ultrasounds aqueous solutions of iron salts, the research group of the Politecnico di Torino has conducted fracture experiments on solid samples, using iron-rich rocks like granite, basalt and magnetite, and then marble, mortar, and steel. Different types of detectors have demonstrated the presence of significant neutron emissions, in some cases by different orders of magnitude higher than the usual environmental background (up to 10 times from granitic rocks, up to 100 times from basalt, up to 1000 times from magnetite).

The neutron flux was found to depend, besides on the iron content, on the size of the specimen through the well-known brittleness size effect: larger sizes imply a higher brittleness, i.e. a more relevant strain energy release, and therefore more neutrons.

These studies have also been able to give an answer to some puzzles related to the history of our planet. It has been shown how the piezonuclear reactions that would have occurred between 3.8 and 2.5 billion years ago, during the period of formation and most intense activity of tectonic plates, have resulted in the splitting of atoms of certain elements, which were so transformed into other lighter ones. Since the product-elements, i.e., the fragments of the fissions, appear to be stable isotopes, all the excess neutrons are therefore emitted. Several of the most abundant chemical elements have been involved in similar transformations, like a part of magnesium that transformed into carbon, forming the dense atmospheres of the primordial terrestrial eras. In a similar way, calcium depletion contributed to the formation of oceans as a result of fracture phenomena in limestone rocks.

Considering the entire life of our planet and all the most abundant chemical elements, it can be seen how ferrous elements have dramatically decreased in the Earth's Crust (–12%), as well as at the same time aluminum and silicon have increased (+8.8 %). An increment in magnesium (+3.2 %), which then transformed into carbon, has been assumed as the origin of carbon-rich primordial atmospheres. Similarly, alkaline-earth elements have strongly decreased (–8.7 %), whereas alkaline elements (+5.4 %) and oxygen (+3.3 %) have increased. The appearance of a 3.3% oxygen represents the well-known Great Oxidation Event, a phenomenon that led to the formation of oceans and the origin of life on our planet.

These transformations, that have lasted for billion years in the Earth's Crust, have been reproduced in the laboratory in a fraction of a second by crushing different rock samples. We were able to confirm, through advanced micro-chemical analyses, the most relevant compositional variations described above at the geological and planetary scales: the transformation of iron into aluminum, or into magnesium and silicon (in iron-rich natural rocks), as well as the transformation of calcium and magnesium into other lighter elements including carbon (in the samples of marble). Such variations are shown to be not modest at all. The iron decrement in magnetite was found to be of 27.9%, compared to an overall increment of 27.7% in lighter elements. So in marble, carbon has increased by 13%, compared to an exactly equivalent overall decrement in heavier elements.

In-situ monitoring at the San Pietro - Prato Nuovo gypsum mine in Murisengo

Since July 1st, 2013, a dedicated in-situ monitoring at the San Pietro - Prato Nuovo gypsum mine, located in Murisengo (Alessandria, Northern Italy) has started and it is still in progress.

The preliminary experimental results refer to a multi-parametric monitoring carried out during a period of 5 semesters, from July 1st, 2013, to December 31, 2015. These experimental observations reveal a strong correlation between the three fracto-emission peaks (acoustic, electromagnetic, and neutron) and the major earthquakes occurred in the closest areas.

In particular, the statistical analysis of the distribution of seismic events and of the three fracto-emissions was performed by means of a multi-modal (multi-peak) statistical approach.

Given a specific discrete distribution of points and applying suitable computational routines, the software (Microcal Origin) determines the relative maxima of the distribution and evaluates the best Gaussian fitting by symmetrical or non-symmetrical bell-shaped curves.

Regarding the seismic activity, during the 921 days of the preliminary investigation, 242 earthquakes of magnitude greater than 1.8 degrees in the Richter scale, within a geographical circular area of 100 km radius, were observed. The threshold of 1.8 was selected since, considering the experimental evidences, this was found to be a sort of seismic off-set below which no significant change in the neutron flux was observed.

By applying the multi-modal statistics to the temporal distribution of the 242 earthquakes detected during the five semesters of monitoring, 31 distinct seismic swarms with a maximum magnitude between 2.5 and 4.7 degrees in the Richter scale were identified. Similar multi-modal evaluations were also performed for acoustic, electromagnetic, and neutron emissions.

From the comparison between the different diagrams, it is evident the strong correlation between acoustic, electromagnetic, neutron signals and the seismic swarms occurring in the surrounding areas. The three fracto-emissions tend to anticipate the next seismic event with an evident and chronologically ordered shifting. In particular, it was noted how the acoustic emissions anticipate the earthquakes by about one day, the electromagnetic emissions by three-four days, whereas the neutron emissions by about one week. Therefore, they should be considered as precursors of the next major earthquake rather than aftershocks of the previous one, on the basis of the statistical signal processing and of the different temporal distances. As an example, in Figure 2a-c it is reported the comparison between a sesimic swarm detected during the preliminary experimental campaign and the correlated fracto-emission distributions. The seismic event refers to the seismic swarm of April 2015 whose main event of 3.2 degrees in the Richter scale occurred on April 11, 2015. From the comparison it can be seen that the fracto-emissions anticipate the seismic activity very clearly, with an evident, although different, shifting.

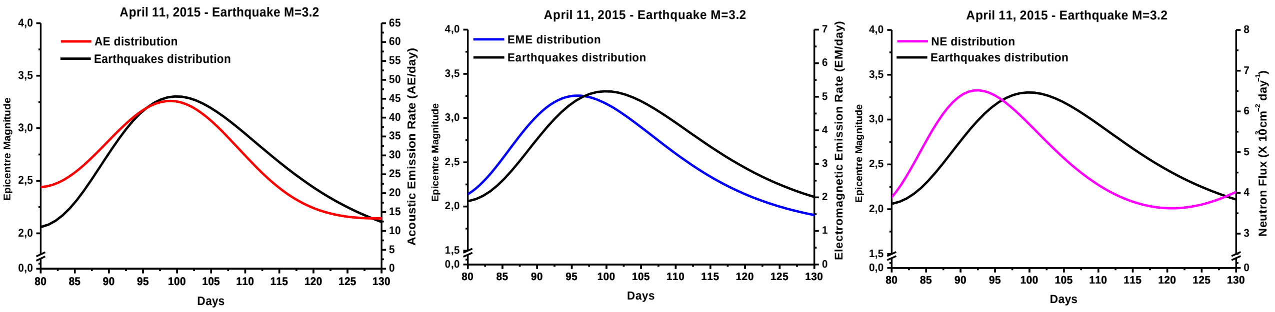

Figure 2a-c: Anticipated and differently shifted Gaussian distributions of AE/EME/NE emissions for the earthquake of April 11, 2015.

Conclusions

Fracture experiments on natural rocks have recently demonstrated that high-frequency pressure waves are able to induce nuclear fission reactions on medium weight elements. Through advanced micro-chemical analyses, the transformation of iron into aluminum, or into magnesium and silicon (in iron-rich natural rocks), as well as the transformation of calcium and magnesium into other lighter elements including carbon (in the samples of marble) was observed. In addition, considering the very important case of earthquakes, the experimental results obtained at the San Pietro - Prato Nuovo gypsum mine emphasize the close correlation between acoustic, electromagnetic, neutron emissions and seismic activity. In particular, it was observed that the three fracto-emissions regularly anticipate the seismic event by approximately one day, 3-4 days, and one week, respectively.

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