

## *Gift 2016 · Natural Hazards*



*Geosciences Information for Teachers Workshop  
Merida, Yucatán, México, 5-8 October 2016*

## **Geosciences Information for Teachers GIFT Workshop – Merida 2016**

### **“Natural Hazards, Disaster Risks and Societal Implications”**

Dear Teachers,

Welcome to the 24th GIFT workshop of the European Geosciences Union and the 2<sup>nd</sup> here in Merida! This year the workshop will unite about 50 teachers around the general theme « Natural Hazards».

Natural hazards are potential threats to humans that begin within and are transmitted through the Earth's natural environment, including the lithosphere, hydrosphere, atmosphere and biosphere. Examples of natural hazards include earthquakes, volcanoes, tsunamis, mass wasting, floods, climate (severe storms, strong winds, droughts) and wildfires. Natural hazards do not just originate on Earth, but can also be extra-terrestrial, such as asteroids potentially hitting the Earth, or solar storms.

Both the causes and results of natural hazards provide a dramatic intersection between the physical and social sciences. Many disasters that occur are a complex mix of natural events and human processes, including political, social and economic. Financial losses due to natural hazards, and the impact of disasters on society, have both increased dramatically over the last couple of decades. All spheres of society are now touched to some extent by natural hazards, whether they involve loss of lives and homes, an increasing strain on country/global resources (particularly acute for developing countries) or the more removed observation of disasters via public media.

Scientists, both physical and social, policy makers, reinsurance companies, disaster managers, and the public themselves, have different ways for understanding and studying natural hazards. These range from mathematical equations, computer models, laboratory experiments, and many kinds of ground-based and satellite data, to interviews, philosophical constructs, compilation of many kinds of social sciences data, and ultimately policy.

Here, in the two and a half days of the workshop we will have time to describe and discuss only some of the more topical natural hazards issues currently facing society via a number of presentations by worldwide known scientists who have made this displacement for you and your students. But we hope these will help you in transmitting these notions to your pupils and we also offer you a set of hands-on activities that, we hope, will soon be a standard in your schools!

As in every GIFT Symposium, you will have a mix of presentations and of hands-on activities, to which you are expected to actively participate.

The GIFT workshop is sponsored not only by EGU, but also by several science organizations. We would like to continue to offer teachers the opportunity to attend GIFT and similar workshops, but this depends upon us being able to show our sponsors that teachers have used the new GIFT information and science didactics in their daily teaching, or as inspiration for new ways to teach science in their schools.

Therefore, we ask you

1. to fill out the evaluation forms as soon as possible and send them back to us;
2. to make a presentation of your experiences at GIFT to a group of your teaching colleagues sometime after you return from EGU, and
3. send us reports (in English!) and photographs about how you have used the GIFT information in your classrooms. We also encourage you to write reports on the GIFT workshop in publications specifically intended for geosciences teachers.

Information on past and future GIFT workshop is available on the EGU homepage. Look at <http://www.egu.eu/media-outreach/gift/gift-workshops.html> where you can find the brochures (pdf) and also the slides of the different presentations given at the GIFT workshops for the last 8 years. Beginning in 2009, we have also included web-TV presentations, which may be freely used in your classrooms.

We hope you'll enjoy this second GIFT workshop in Merida!

The Organising Committee

**Geosciences Information for Teachers GIFT Workshop – Merida 2016**  
**“Natural Hazards, Disaster Risks and Societal Implications”**  
Venue: Hotel Fiesta Americana, Merida, Yucatan, Mexico  
October 5, 6 and 7, 2016

# Program

## Wednesday, October 5th, 2016

- 09:00-9:15 Welcome Address**  
V́ctor Caballero Durán  
*Minister of Education of Yucatán*
- 09:15-9:30 Welcome and practical instructions for the workshop**  
Carlo Laj,  
*Chair, Committee on Education*  
*European Geosciences Union*
- 09:30-10:30 Introduction to Natural Hazards**  
Jaime Urrutia Fucugauchi,  
*Mexican Academy of Sciences & Universidad Nacional Aut3noma de M3xico*

### 10:30 – 11:00 Coffee Break

- 11:00-12:00 Origin of earthquakes in Latin America**  
Raúl Madariaga  
*École Normale Supérieure, Paris France &*  
*Universidad de Chile, Santiago, Chile*

### 12:00 – 12:30 OPEN QUESTIONS SESSION 1

### 12:30 – 14:00 Lunch

- 14:00-15:00 Virtual Volcanoes: Computer Simulations of Volcanic Eruptions**  
Paolo Papale  
*Istituto Nazionale di Geofisica e Vulcanologia, Italy*
- 15:00-18.30 Earthquake studies in the Classroom:**  
**Presentation of «The Seismo box: do it yourself»**  
François Tilquin<sup>1</sup> and Francesca Cifelli<sup>2</sup>  
<sup>1</sup>*Lycée Marie Curie, Echirolles, France*  
<sup>2</sup>*Università degli Studi Roma TRE*

### 18:30 – 19:00 OPEN QUESTIONS SESSION 2

**End of the Day!**



## Thursday, October 6, 2016

**09:00-10:00 Volcanic hazards, Eastern Mexican volcanic belt**

Gerardo Carrasco

*Centro de Geociencias, Juriquilla, Querétaro*

**10:00-11:00 Seismic hazards in Mexico**

Xyoli Perez Campos

*Unión Geofísica Mexicana*

**11:00-11:30 Coffee Break**

**11:30-12:30 Geophysical studies and volcanic hazards**

Jaime Urrutia Fucugauchi

*Mexican Academy of Sciences*

**12:30-14:00 Lunch**

**14:00-15:00 Discover floods: Suggestion to educate kids and young to flood prevention**

Giorgio Boni

*University of Genova, Italy & Natural Hazards Division EGU*

**15:00-16:00 Tsunamis**

**David Salas de León**

*Instituto de Ciencias del Mar y Limnología, UNAM*

**16:00-19:00 Instructions and materials for building the Seismobox**

François Tilquin<sup>1</sup> and Francesca Cifelli<sup>2</sup>

<sup>1</sup>*Lycée Marie Curie, Echirolles, France*

<sup>2</sup>*Università degli Studi Roma TRE*

**19:00 End of Day 2**

## Friday October 7, 2016

**09:00-10:00 Eruptions from calderas: The most devastating the least understood**

Paolo Papale

*Istituto Nazionale di Geofisica e Vulcanologia, Italy*

**10:00-11:00 Risk Analysis**

Zenón Medina Cetina

*Texas A&M University, College Station*

**11:00-11:30 Coffee Break**

**11:30-12:30 Communicating science through humor, does it work?**

Susana Alaniz

*Centro de Geociencias, National University of Mexico*

**12:30:13:30 Vulnerability of karstic aquifers in Yucatan**

Mario Rebolledo Vieyra,  
*CICY, Yucatán*

**13:00-14:00 Lunch**

**14:00:15:00 The Amatrice Earthquake, Italy:geophysical and social aspects**

Alessandro Amato  
*Istituto Nazionale di Geofisica e Vulcanologia, Italy*

**15:00 Final Remarks**

Optional Trip

October 7th

Visit to the Chicxulub Science Museum and the Yucatan Science and Technology Park

*Speakers*

**Raul Madariaga**

Professor emeritus  
Department of Geosciences  
Ecole Normale Supérieure,  
75231 Paris Cedex 05, France  
madariag@geologie.ens.fr  
Tel (0033-6-82681387)  
personal webpage:  
[www.geologie.ens.fr/~madariag](http://www.geologie.ens.fr/~madariag)

**EDUCATION**

1961-1967 Civil Engineer School of Engineering University of Chile.  
1967-1971 Graduate studies at the Massachusetts Institute of Technology  
June 1971 Ph.D. in Geophysics from M. I. T.

**CAREER**

Assistant Professor, Department of Geophysics, University of Chile, Santiago, 1971-1973  
Research Associate, Department of Earth and Planetary Sciences, M.I.T. 1974-1976.  
Physicien Adjoint, Institut de Physique du Globe de Paris, 1977-1979.  
Associate Professor. Earth Sciences Department Université Paris VII, 1979-1984.  
Full Professor, exceptional class Université Paris VII, 1984-1991, 1991-1998.  
Senior Member of Institut Universitaire de France, 1993-1998.  
Professor of exceptional class, Ecole Normale Supérieure, 1998-2012.  
Profesor emeritus Ecole Normale Supérieure, 2012-

**RESEARCH INTERESTS**

Seismology, applied Geophysics, Earthquake physics, Subduction zones, Seismicity

**PUBLICATIONS AND SERVICES**

More than 150 papers (<http://www.geologie.ens.fr/~madariag/Publications.html>)

**Books:**

Madariaga, R. and G. Perrier, Les Tremblements de Terre, Les Editions du CNRS, 1991.  
Udias, A., R. Madariaga and E. Buforn, Source Mechanisms of Earthquakes, theory and practice. Cambridge University Press, Cambridge, U.K. isbn: 9781107040274

**SERVICES:**

Director Seismological Laboratory, Institut de Physique du Globe de Paris and Université Paris 7 1985-1997.  
Director of the Seismic Research Group of CNRS, Elf Aquitaine and IFP. 1987-1992.  
Director Geology Laboratory of Ecole Normale Supérieure, 2000-2006

**AWARDS AND HONORS**

Prix d'Aumale of Institut de France (Academy of Sciences) 1980.  
Fellow American Geophysical Union, 1991.  
Prix Antoine D'Abbadie of Academy of Sciences, 1992.  
Senior Member of Institut Universitaire de France, 1993-1998.  
Grand Medal of the President of the University of Chile, 1998.  
Stephan Mueller Medal of the European Geophysical Society, 1999.  
Harry F. Reid Medal of the Seismological Society of America, 2004.

# ORIGIN OF EARTHQUAKES IN LATIN AMERICA

**Raul Madariaga**

Département de Géosciences, Ecole Normale Supérieure, Paris France

Departamento de Geofísica, Universidad de Chile, Santiago, Chile

## **Abstract**

Earthquakes are a very common natural disaster in all of Latin America, from Southern Chile to Northern Mexico and beyond in North America. These earthquakes are mainly due to subduction of the plates that form the bottom of the Pacific Ocean under the Americas. This subduction process is quite fast, from 6-7 cm/year under Southern Chile to up to 11 cm/year under Central America and some 8 cm/year under some regions of Mexico. Subduction not only produces earthquakes, it also created a large number of active volcanoes like those of Chile, Peru and Ecuador and those of Mexico's volcanic axis. At several places along the Pacific margin the subduction processes are more complex, producing several features that create so-called extensional margins, like that of the Gulf of Baja California in Northern Mexico. The relation between geographical and geological features and seismicity is often called seismotectonics. We will discuss some of its main features in South America and Mexico.

## **What is an earthquake?**

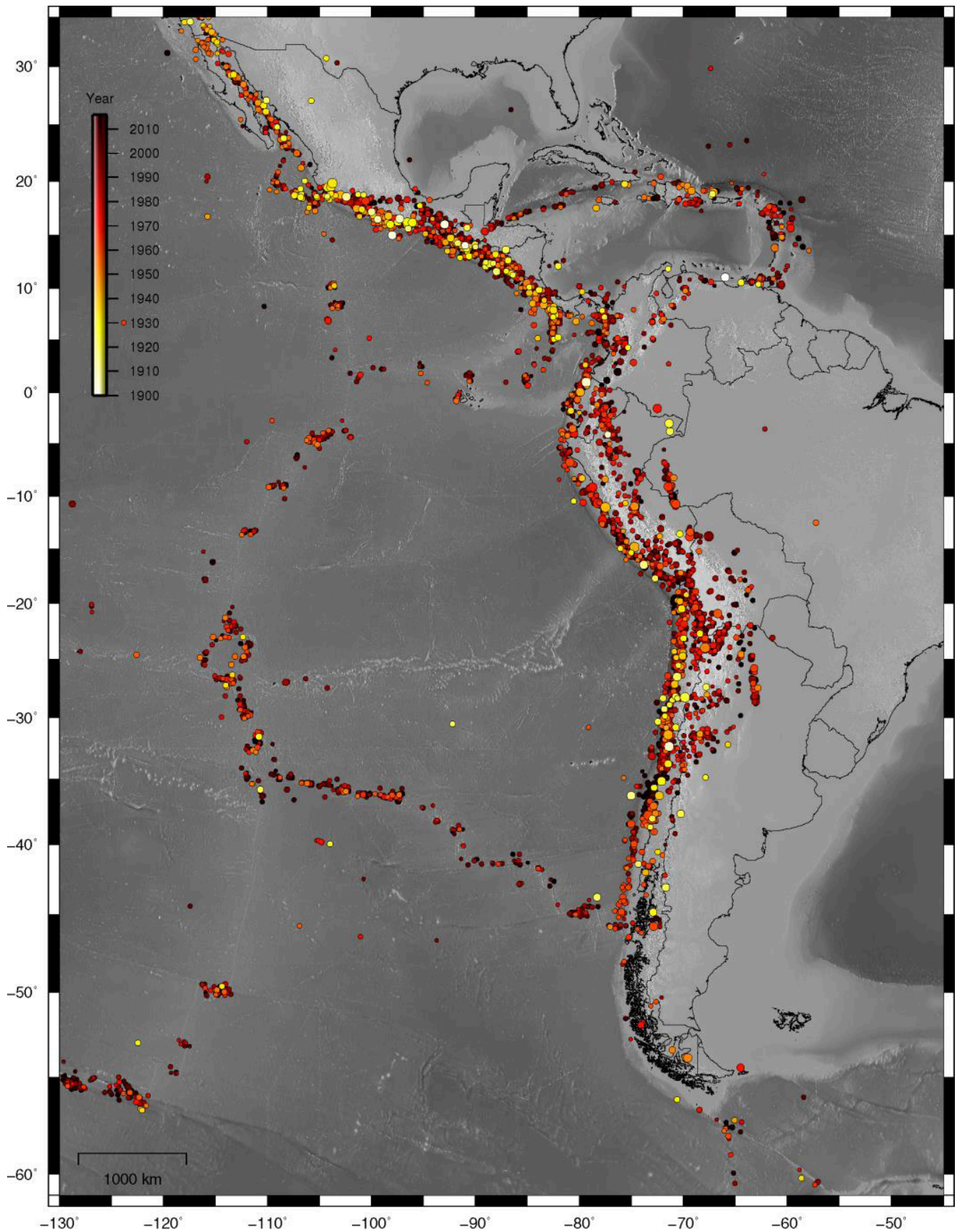
Earthquakes are due to slip of faults in the Earth. Faults are one of the most pervasive features of shallow geology. Faults come in all sizes, from very little ones on any mountain to really big ones like those that bound lithospheric plates. Earthquakes are due to sudden motion on one of these faults. Slip on faults is the main ingredient of earthquakes, but for these events to be catastrophic slip has to occur at very fast speeds so that seismic waves are generated. Elastic waves come in two basic kinds: compressional or P waves and shear or S waves. Shear waves propagate in the earth at speeds of the order of 3.5-5 km/s, while P waves are about 70% faster. Earthquakes require these two ingredients: faulting and seismic wave propagation. Not all faults in the earth slip fast enough to generate strong seismic waves. This is the case of silent earthquakes that occur at slow speed so that no waves are generated. These events are common in Mexico, Chile, Ecuador and Costa Rica and the NW USA.

## **How do we measure earthquakes?**

The most common way of measuring an earthquake is to determine its magnitude. This is the strength of the source at the hypocenter. Initially, around 1940 magnitude was determined empirically using the amplitude of seismic waves, but this method was soon rendered obsolete. It was established around 1960 that faulting in the earth produces quadrupole radiation. A quadrupole is a distribution of amplitudes around the source that has four lobes.

The amplitude of seismic waves radiated by a fault is directly proportional to the moment  $M_0$  of the quadrupole. Because traditionally earthquakes were measured by their magnitude, seismologists devised a simple way to connect the seismic moment  $M_0$  measured in units of Nm (Newton meter) to their magnitude  $M_w$ . The expression is the following:

$$\log M_w = 1.5 M_0 + 9.1$$



*Figure 1. Seismicity of Latin America and adjacent oceanic areas. The most outstanding feature is the almost continuous distribution of earthquakes associated with the subduction zones of the Pacific rim of the Americas.*

Since the units of moment are not at all intuitive to humans, it is more efficient to use magnitudes. In



the following we provide a Table that converts from magnitude to moment and at the same time we provide the size of the earthquake fault, the duration of the earthquake and the amount of slip on the fault. These are typical values for earthquakes of different magnitudes. Individual events present strong variability.

This is sometimes called the scaling law of earthquakes.

Magnitude ( $M_w$ )	Moment (Nm)	Longueur (km)	Durée (s)	Glissement (m)
10	$10^{24}$	1000?	300?	100?
9	$3 \cdot 10^{22}$	300	100	30
8	$10^{21}$	100	30	10
7	$3 \cdot 10^{19}$	30	10	3
6	$10^{18}$	10	3	1

*Table 1. Relation between Magnitude, seismic moment, length, duration and slip for earthquakes of different size.*

As soon as the previous scale was devised, seismologists realized that the moment could be computed from the slip on the fault and the area of the region that slipped during the earthquake. At the global scale moments are estimated very quickly after all earthquakes of magnitude greater than 4, that is all events that are detected by populations. These are the basis for issuing seismic alerts and early warning of impending catastrophes.

### **Small and large earthquakes**

Earthquakes occur everywhere all the time, most are only felt by small groups of people in the immediate vicinity of the event. An earthquake is generally felt by large groups if their magnitude is larger than 4 and will affect large areas if it is larger than 6. Sometimes events of magnitude around 6 can be catastrophic if they are very shallow (like the earthquake in Haiti in 2009) or very close to populations as in Ecuador earlier this year. When seismic events have magnitudes greater than 7, they become felt in large areas and produce strong damage. Seismic events with magnitude greater than 8 are usually catastrophic and produce large damage, may generate tsunamis and strong effect on sedimentary basins, highways, buildings, etc. Large earthquakes in the Americas most often occur in subduction zones because of slip between the subducted (down-going) plate and the upper continental plate.

### **Where do large earthquakes occur?**

Fortunately large earthquakes are very rare. It has become customary in recent years to use different words for such large earthquakes instead of simply referring to their magnitude. Thus the very rare event that occur every three or more centuries in any subduction zone are called mega thrust earthquakes. The best known of these are the Chile 9.6 earthquake of May 22, 1960, the great Alaska

earthquake of 1964,

the Colombia earthquake of 1906 or the recent earthquakes in Sumatra 2004, Tohoku 2011 and the great Maule earthquake of 2010. These events produce major changes in subduction zones, release huge amounts of accumulated energy and, depending where they occur they produce tsunamis that cross the Pacific Ocean. A typical megathrust earthquake has a magnitude greater than 8.8. Next in destructive power, come earthquakes of magnitudes 7.5 to 8.6 which produce large local destruction, small. The best example of such an event is the Michoacán earthquake of 1985 that although it produced mild effect in its epicentral area, produced huge damage in Mexico City. Smaller events of magnitudes less than 7.5 much more frequent and except when they occur at very shallow depths near cities with poor seismic protection, they produce limited damage.

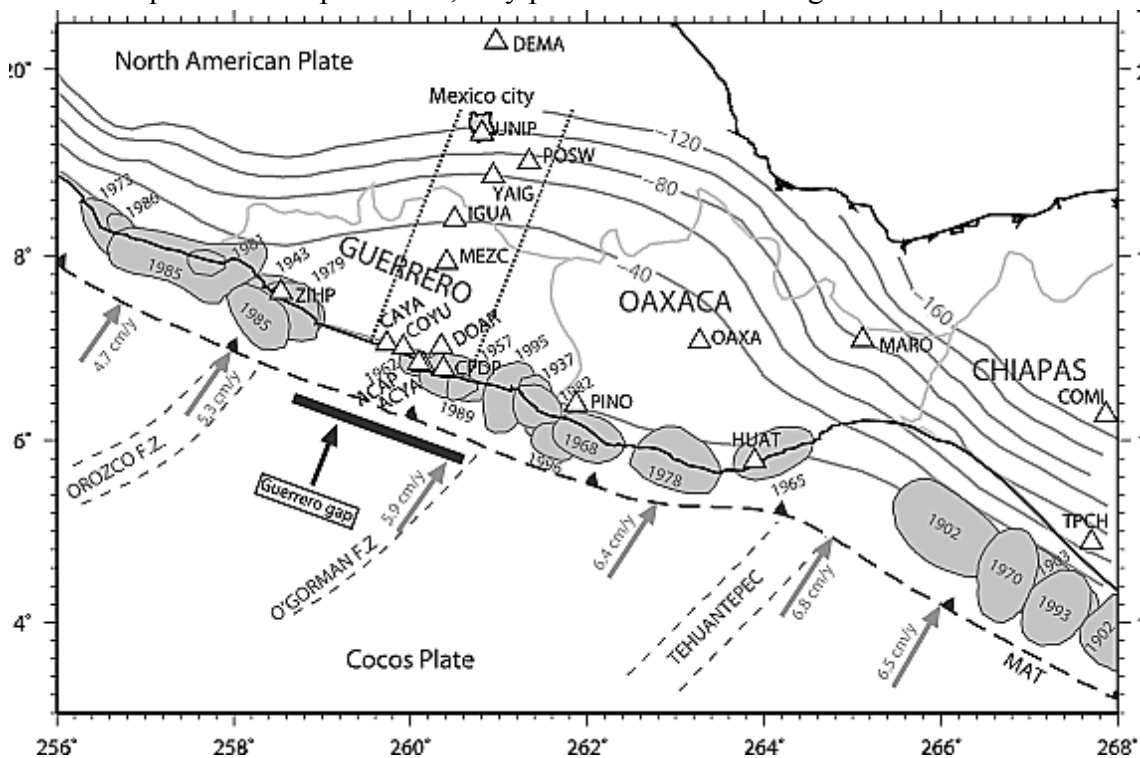


Figure 2. Major earthquakes along the Mexican subduction zone. An outstanding feature is the Guerrero gap, a zone where no large earthquake has occurred in at least 80 years. It is the site of slow slip events.

### The process of stress accumulation in subduction zones.

In 1906 a large earthquake occurred on the San Andreas Fault right under San Francisco producing great damage to the city and its environs. A commission was designated to study the origin of the earthquake. The report of the commission written by Reid in 1912 concluded that earthquakes on the San Andreas Fault occur only in the shallow part of the crust down to about 15 km and that below this depth slip occurs continuously by a process called "creep" or aseismic slip.

The upper crust being locked by friction it accumulates stress for long periods of time until the rocks surrounding the fault can no longer sustain the stress. Then a large earthquake may occur producing large slip near the surface. This process of accumulation and release of stress was called "elastic rebound".

### Subduction earthquakes and plate tectonics

In subduction zones a process similar to that Reid is also at work. In the 1960s studies of the ocean bottom showed unmistakably that these moved with respect to continents and that oceans were not permanent features of the earth. They were created at mid ocean ridges and disappeared at subductions zones. These were the next extensively mapped and compared leading to the very complete view that

we have today of the main plates that conform the surface of the earth and paved the bottom of the Pacific Ocean. In the Pacific, as shown in Figure 1, these plates are created at the mid Pacific rise a large zone of mountains that underlain the East Pacific and emerges in land in Northern Mexico in the Baja California Peninsula. Everywhere else plates are generated and move laterally at great speeds of the order of 5 to 15 cm/years until they disappear in the subduction zones of Peru-Chile, Colombia Central America, Southern Mexico and Guatemala producing large earthquakes in rare occasions. The model of Reid was adapted to subductions zones in the so-called back slip model of Savage. This author proposed that under every subduction zones there was a zone of continuous slip that started roughly near 40-45 km of depth. At shallower depths the oceanic plate was held by friction impeding the natural tendency for oceanic plates to drop themselves in the mantle. It is the occasional release of friction in subduction zones that produces earthquakes in these regions. Figure 8 shows the general features of this model and the process of accumulation and release of stress that leads to very large earthquakes. It was only in the early 1990s that this mechanism was confirmed thanks to Space Geodesy, mainly GPS the same satellites that permit location of cellular phones and other small antennas in the surface of the earth. Geodesists developed very accurate techniques to detect the motion of antennas installed on the surface of the earth. These can nowadays detect minute motions only slightly larger than a mm per year. Deploying these antennas is technically difficult but it has become very extensive, producing large amounts of data that confirm the process that lead to stress accumulation and sudden release in subduction zones. We will show the most spectacular observations made in Chile before and after the 2010 earthquake.

## Elastic Rebound model for subduction zones

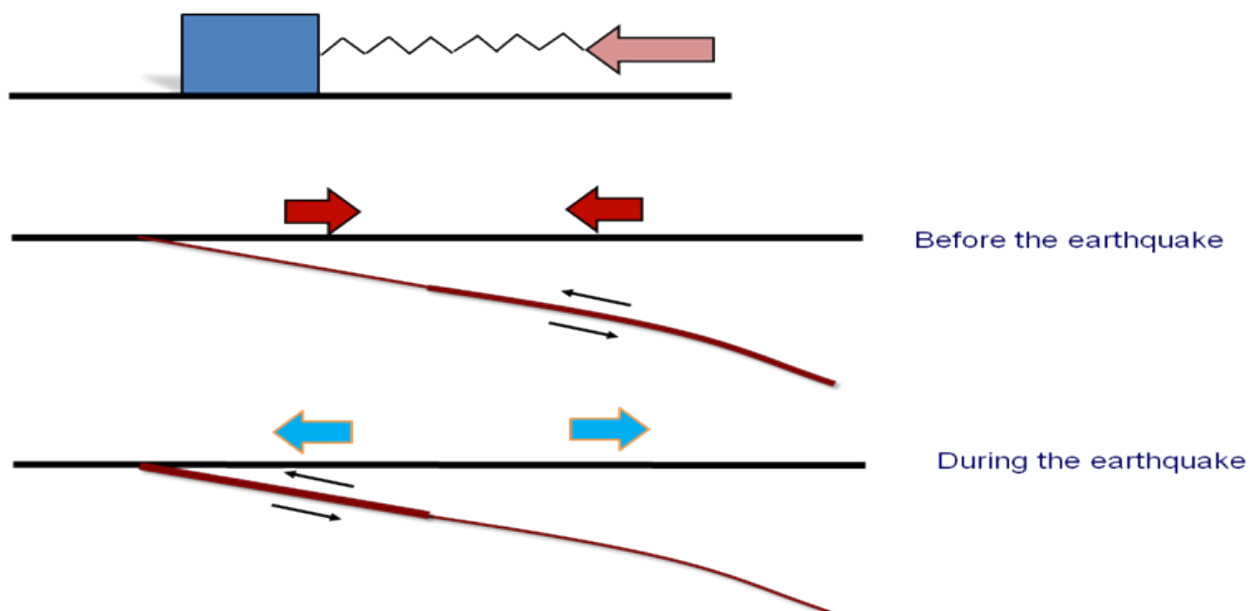


Figure 3. Elastic rebound model for a subduction zone. Often referred to as the back slip model for subduction zone seismicity. Before the earthquake, continuous slip at depth accumulates compressive stresses (red arrows) above the subduction zone. During the earthquake slip occurs at shallow depth in the plate interface producing extensive stresses (blue arrows).



## **Paolo Papale**

Istituto Nazionale di Geofisica e Vulcanologia  
Via Della Faggiola, 32  
56126 Pisa, Italy  
+39 050 83119-31  
papale@pi.ingv.it

### **Education**

- Degree in Geological Sciences 1989 Dept. of Earth Sciences, University of Pisa, with Full Honours

### **Position current**

- Director of Research at INGV
- Responsible of the INGV Center for Volcanic Hazards

### **Positions past**

- 2003-present Research Director, INGV
- 1999-2003 Researcher – ING/INGV
- 1996-1999 Contract Researcher, CNR
- 1990-1996 Contracts and Fellowships with ING, CNR, Univ. of Pisa

### **Appointments**

- Director, Volcanoes Division of INGV, 2013 – 2016
- Head of the Unit “Physico-mathematical Modelling and Numerical Simulation of Volcanic Processes”, INGV, 2006 - 2013
- DPC Committee for the preparation of the Emergency Plan at Campi Flegrei volcano, 2009 – 2011
- Scientific Advisory Council, INGV, 2007-2008
- Presidential Advisory Board, EGU, in representation of the scientific theme “Solid Earth”, 2007-2009
- Awarding Committee, EGU Robert Wilhelm Bunsen Medal, 2005 – to date, Chair since 2010
- Awarding Committee, EGU Arthur Holmes Medal and Honorary Membership, 2010 – to date
- Chair of Awarding Committee, EGU/GMPV YSOPP: “Young Student Outstanding Poster Presentation” award, 2009 – 2011
- Chief and Funding Editor, Solid Earth, published by EGU, 2009 – to date
- Editorial Board, Journal of Volcanology and Geothermal Research, 1998-2006
- Scientific Managing Committee, GNV, 2002-2004

### **Scientific Output**

- > 60 refereed papers in international journals and books
- Nearly 2000 ISI Web of Science Citations (Papale P\*)
- h-factor = 25

### **Advisory Roles**

- Panel of NSF Merit Reviewers
- Panel of EU FP7 Reviewers, Programmes “People” and “Ideas”
- Panel of Reviewers, Belgian Government, Remote Sensing Research Programme
- Panel of Reviewers, French USAR – Gestion de Programmes de Recherches
- Panel of Reviewers, Italian Research Programme PRIN
- Reviewer for the main scientific journals in Geosciences (Nature, Nature Geosciences, Journal of Geophysical research, Geophysical Research Letters, Earth Planetary Science Letters, Bulletin of Volcanology, Journal of Volcanology and Geothermal Research, etc.)
- Chair of the GMPV Programme Committee, European Geosciences Union General Assemblies 2008-2009-2010 (about 100 scientific sessions organized)
- 20+ Graduating/Doctoral Students supervised
- 10+ Postdoctoral collaborators

### **Synergistic activities**

- European Coordinator, FP7 Marie Curie Initial Training Network “NEMOH - Numerical, Experimental and stochastic Modelling of vOlcanic processes and Hazard: an Initial Training Network for the next generation of European volcanologists”, 2012 – to date
- Principal Investigator, FP7 Cooperation “VUELCO - Volcanic Unrest in Europe and Latin America: Phenomenology, eruption precursors, hazard foreCast, and risk mitigation, 2011 – to date
- President, Geochemistry, Mineralogy, Petrology and Volcanology Division – European Geosciences Union, 2007- 2011
- National Coordinator of the INGV-DPC Projects in Volcanology, 2004-2006 and 2007-2009, and Head of Managing Committee
- Secretary, Volcanology Sub-Division – European Geosciences Union, 2005 – to date
- United Nations Commission for the Nyiragongo-Lake Kivu crisis 2002

### **Invited presentations (selected)**

- 18th Symposium of the International School of Geophysics, Erice (Sicily), 2001: Physico-chemical magma properties and eruption dynamics.
- European Volcano Dynamics Research Training Network, 3rd Workshop, Azores, 16-26 May, 2003: Numerical modelling of volcanic processes.
- GIV Summer School of Volcanology, Catania (Sicily), June 2003: Numerical modelling of volcanic conduit processes.
- European Volcano Dynamics Research Training Network, 4th Workshop, Napoli, 12-16 January, 2004: Roles of volatiles in sub-surface volcanic processes.
- International School of Volcanology, Tenerife, Canary Islands, May-June 2004: Volatiles in magmas and their control on volcanic eruption dynamics.
- Seminars at Ludwig-Maximilian University, Munich, April 2005: Relationships between magma properties and volcanic eruption dynamics.
- An Introduction to Quantitative Physical Volcanology – Workshop, Geneva, April 2006: Conduit flow dynamics.
- University of Chieti, Italy, March 7th, 2006: Dynamics of explosive eruptions.
- Architectural Association School of Architecture, London, UK, May 2006: The January 2002 Nyiragongo eruption, DRC.
- ETH Zurich, January 12th, 2007: Magma properties and magmatic and volcanic processes: Complex relationships disclosed by numerical simulations.
- AIV School of Volcanology, Stromboli Island (Sicily), September 2008: Magma dynamics and pre-eruptive signals: the contribute of numerical simulations.
- IAVCEI Conference, Reykjavik, Iceland, August 2008: Linking geophysical observations and magma chamber dynamics at active volcanoes. Part I and Part II.
- Dept. of Earth Sciences, University of Leeds, UK, October 2009: Numerical simulation of magma dynamics and associated geophysical signals.
- American Geophysical Union Fall Meeting, December 2010: Current and future trends of volcanology in Italy and abroad.
- Fragile Earth International Conference, Munich September 2011: Towards a globally consistent dynamic picture of pre-eruptive eruption dynamics.
- AIECS – Academia Europea, Graz, 30-31 Agosto 2010: Volcano modelling: control of deep magma dynamics on geophysical network signals.
- 150° Anniversary of Geophysical Institute in Zagreb, December 2011: Recent achievements in volcanology.
- GIFT workshop, Istanbul, March 2014.

# **ERUPTIONS FROM CALDERAS: THE MOST DEVASTATING, THE LEAST UNDERSTOOD**

**Paolo Papale**

Istituto Nazionale di Geofisica e Vulcanologia, Italy  
([papale@pi.ingv.it](mailto:papale@pi.ingv.it))

Large calderas are the site of the most devastating eruptions occurred on Earth; they often display substantial unrest dynamics that puzzle volcanologists, and in some cases like the Campi Flegrei case, trouble them as well as the society for the enormous risks associated to their eruptions. Calderas display sequences of signals that would almost certainly prelude to an eruption if observed at central volcanoes; nonetheless, volcanic eruptions may not follow, while they may happen with definitely much weaker signals preceding them, as for the Rabaul eruption in 1994. Although largely debated, the origin of this controversial behaviour is still unclear. The caldera structure favours the development of large geothermal circulation, that is often invoked as an important controlling factor for the observed geophysical and geochemical changes. At Campi Flegrei, and possibly at other calderas like Krafla in Iceland, the structural setting appears to have repeatedly favoured emplacement of small magma bodies at very shallow ( $< 3$  km) depth, creating a network of interconnected reservoirs capable to exchange mass and heat. The efficiency of interconnections likely controlled the scale of the eruptions, limiting the role of the shallow magmatic batch and complicating the forecasts. Although our knowledge of caldera systems has evolved substantially, their understanding is still limited, contributing to increase the associated risk.



# **VIRTUAL VOLCANOES**

## **COMPUTER SIMULATIONS OF VOLCANIC ERUPTIONS**

**Paolo Papale**

Istituto Nazionale di Geofisica e Vulcanologia, Italy  
(papale@pi.ingv.it)

Volcanology has evolved during last decades from a branch of the natural sciences to a fully quantitative field of investigation which makes use of the most advanced and sophisticated scientific tools to explore the dynamics of volcanic processes and anticipate the impact of volcanic eruptions. Besides geological observations, which provide the basic knowledge of the structure as well as the eruptive and magmatic histories of volcanoes, the deployment of networks of telemetered instruments guarantees real-time multi-parametric measurements and continuous records of even tiny changes occurring at volcanoes; the use of inverse theories lead to constrain the internal and deep processes occurring at volcanoes; sophisticated laboratories allow to reproduce and measure at scaled conditions an increasing number of properties and processes of real magmas; and computer simulations provide a dynamic view of the processes occurring before and during eruptions, allowing to penetrate the intimate physics of volcanic processes, anticipate volcanic scenarios, and quantify the volcanic hazards. Computer simulations require a complex approach which is based on the definition of the physical laws describing the processes under investigation, like the movement of magma inside the Earth's crust, its acceleration along volcanic conduits, and its dispersal on the Earth's surface in the form of lava fountains and lava flows, or as giant columns of volcanic ash and gas rising kilometres into the atmosphere or collapsing along the volcano flanks in the forms of destructive pyroclastic flows. Because the mathematical equations representing those physical laws are generally too complex to be solved directly, their solution requires searching for sufficiently good numerical approximations through the use of computers. I will show some examples of solutions, in the form of computer animations describing the evolution in time and space of quantities like concentration, velocity, pressure, temperature, etc., through which a large number of aspects of the physics of volcanic eruptions are highlighted, and their impact on men and environment is quantified.



**François Tilquin**

Lycée Marie CURIE

ECHIROLLES

FRANCE

email: francois.tilquin.38@gmail.com

I am a retired biology and geology teacher in a high-school near Grenoble- France. My students were 15 -18 years old.

I am the author of various teaching softwares and pedagogical applications: data acquisition with interface, simulations, numerical and analogical modeling in biology and geology.

Even if it is more difficult, I prefer that students make the manipulations by themselves, and test the hypothesis, than when the professor makes the demonstration himself.

In France, we are lucky to have practical classes with reduced number of students (18 to 30), and we dispose enough experimental material for individual manipulations.

Whenever it is possible, I try to adapt scientific experiments to the class, with some simplifications, and with the advice of the researchers who are always very interested in this transfer of their knowledge.

It was and it is still for me the most important goal of the earth sciences teaching.

(web in Google: sismobox)



**Francesca Cifelli**

Associate Professor

Department of Science, Roma TRE University

email: francesca.cifelli@uniroma3.it

EDUCATION/CAREER

- 1997: Master degree in Geological Sciences at La Sapienza University, Rome
- 1999-2003: Ph.D. in Geological Sciences at Roma TRE University, Rome
- 2003–2006: Post-doc at the Department of Geological Science, Roma TRE University
- 2006-2015: Non-permanent researcher in Structural Geology at the Department of Geological Science, Roma TRE University
- 2015: Associate Professor at the Department of Geological Science, Roma TRE University

RESEARCH INTERESTS

- Paleomagnetic rotations and structural evolution of curved mountain chains
- Extension and dynamics of back-arc spreading in Mediterranean region
- Recent tectonics in Central Iran
- Seismic effects in urban areas
- Science education and outreach

TEACHING AND EDUCATIONAL ACTIVITIES

- Teaching activity includes support in the first year classes and field assistance in structural geology classes
- Tutor and co-tutor of Master theses and PhD theses
- High-school teacher training activity
- Italian responsible of Educational Committee of Education of the European Geosciences Union (EGU) for the organization of the GIFT (Geophysical Informations for Teachers) workshop

# EARTHQUAKES STUDIES in CLASSROOM:

## “SEISMO-BOX: DO IT YOURSELF”

François Tilquin<sup>1</sup> and Francesca Cifelli<sup>2</sup>

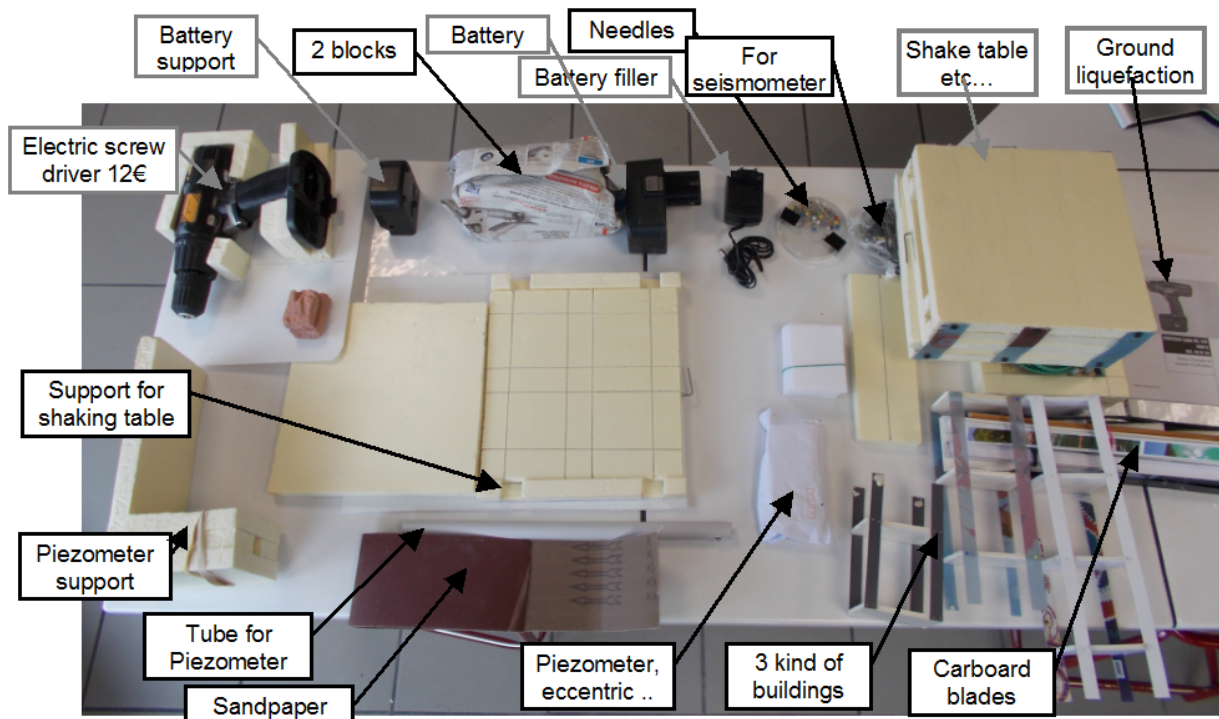
<sup>1</sup>Lycée Marie Curie, Echirolles, France

<sup>2</sup>Università degli Studi Roma TRE, Italy

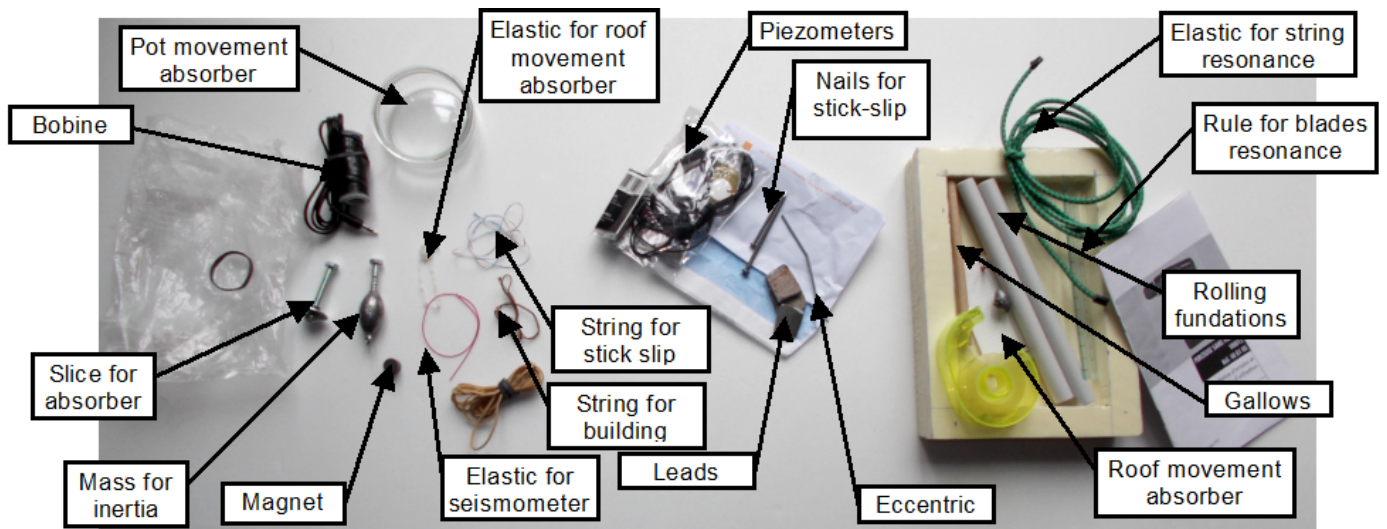
To prevent population against seismic risk, people must know **where** earthquakes take places, **when** earthquakes occur and **how** much is the released energy. The seismo-box has been projected with the main goal to answer these main questions!

Experiments that can be made with the seismo-box allow understanding some important aspects of earthquakes: what is the origin of an earthquake, how to record and locate it, the impossibility to predict it, and what are its consequences on buildings. Moreover, it is possible to understand better the difference between seismic hazard (that man cannot control) and seismic risk (that man can and must minimize).

This ‘Seismo-box: do-it-yourself’ is made with very simple and cheap (and even recycled) materials. Among the most popular experiments possible with the seismo-box: the record of micro-earthquakes, the simulation of vibrations on small buildings, the liquefaction and the stick-slip experiments. Moreover, the free software **AZIMUT**© FT 12/2011 allows showing which are the characteristics of the various waves which arise from an earthquake, and what is the first movement of the ground.

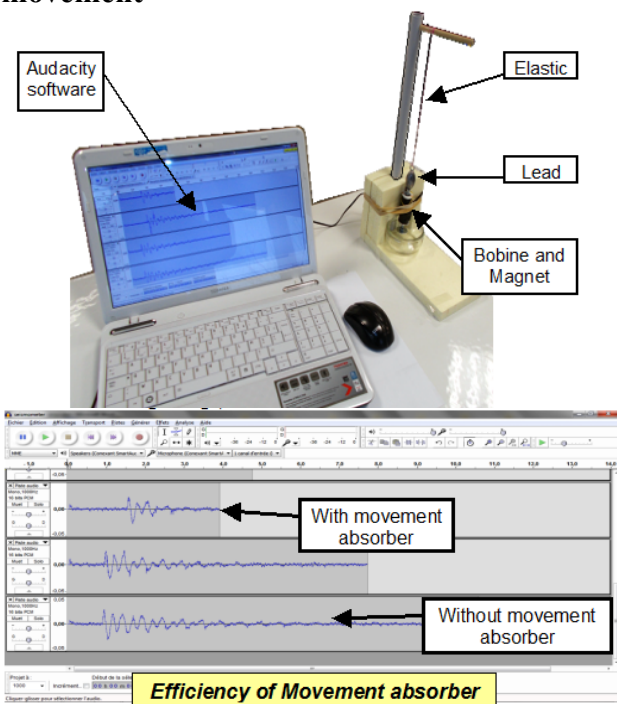


*Contents of the ‘Seismo-box: do-it-yourself’.*

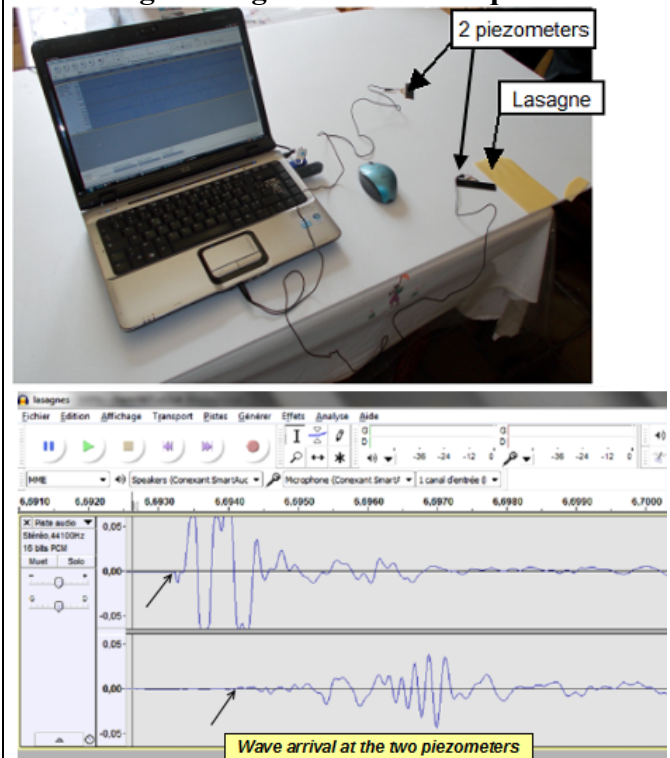


*Details of the material needed to build seismometer or record table-earthquakes.*

### Seismometer recording the ground movement

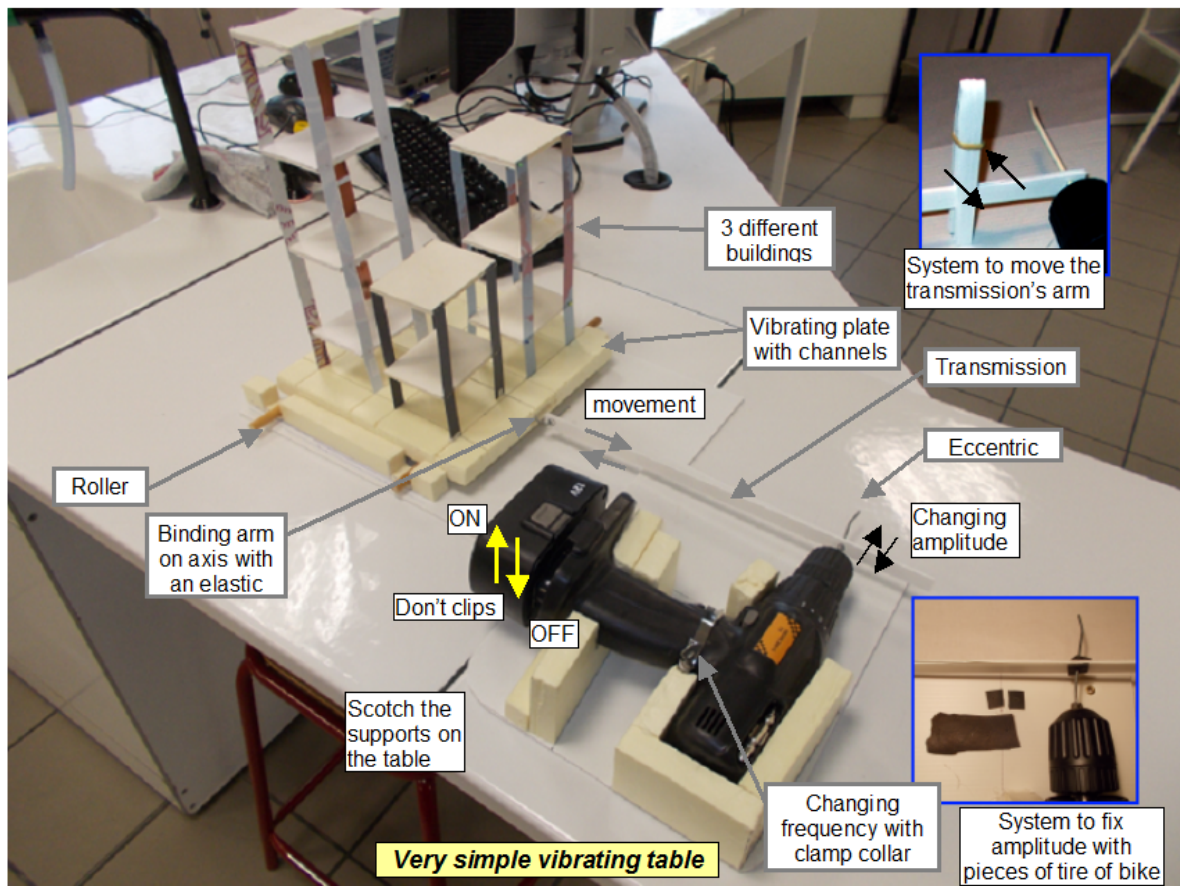


### Recording a 'lasagne' micro-earthquake

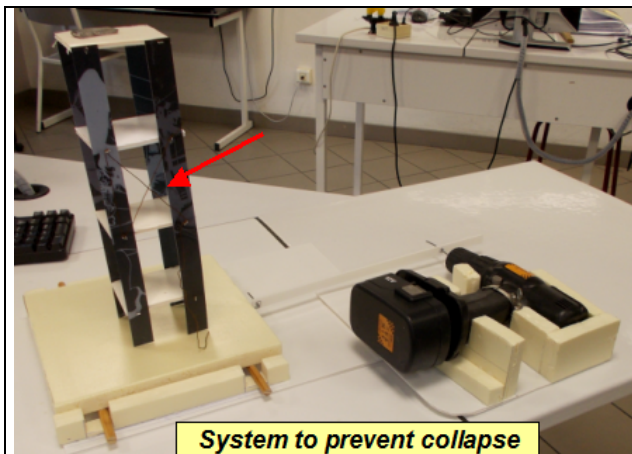


*Details of how to record an 'earthquake'.*

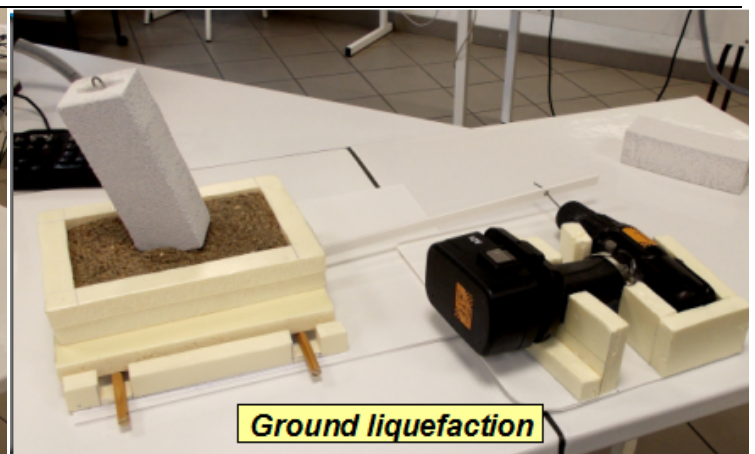




*Shaking table: the very cheap electric screwdriver rotates an eccentric, which converts rotations in longitudinal movements. They are transmitted to a tray with different height buildings and systems. We can change frequency and amplitude of the vibrations and see the resonance problem, and many other scientific processes.*



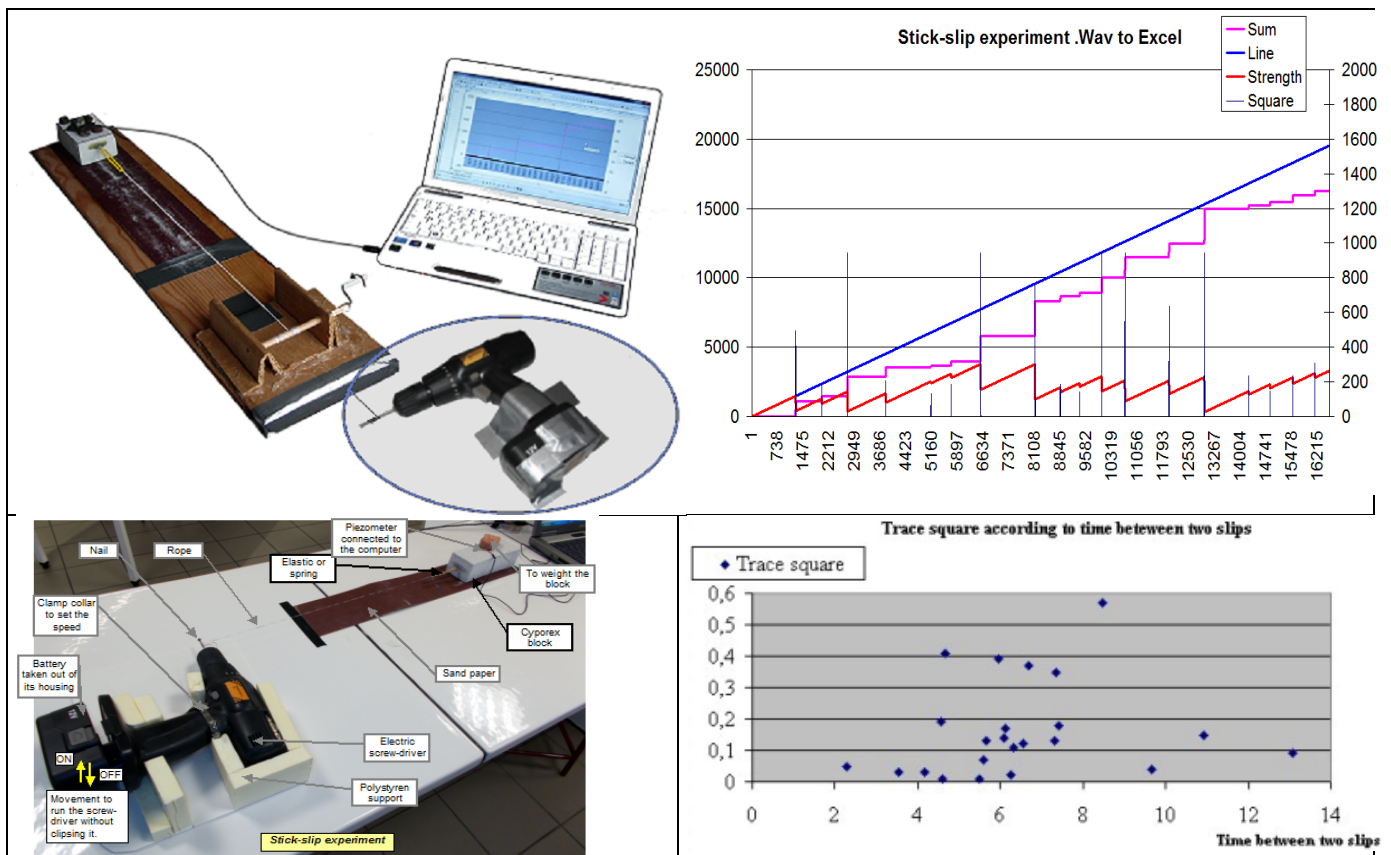
Preservation of building shape with 2 crossed threads.



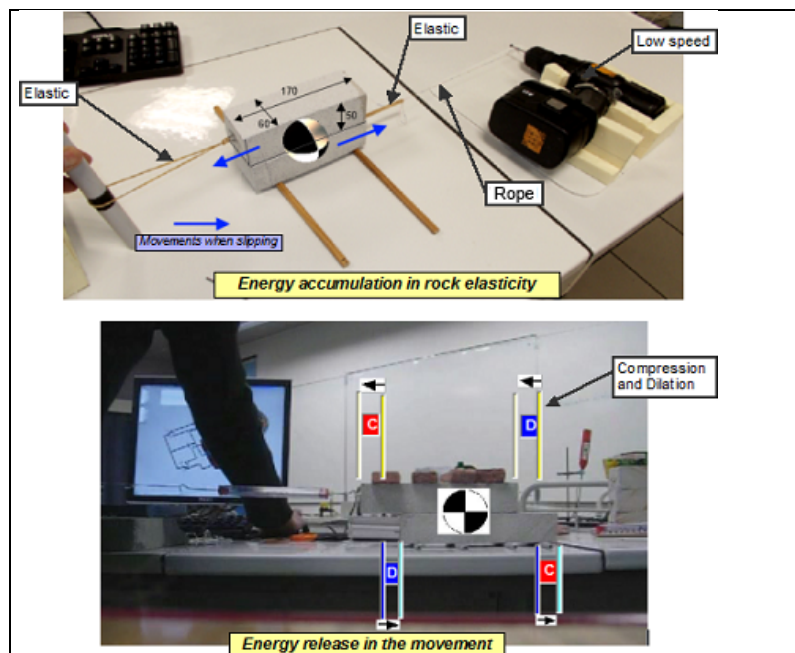
Vibration causes the ground liquefaction, and it's heterogeneousness makes the building falling down

*On the left how to 'reinforce' a building for preventing its damage. On the right the liquefaction phenomenon.*

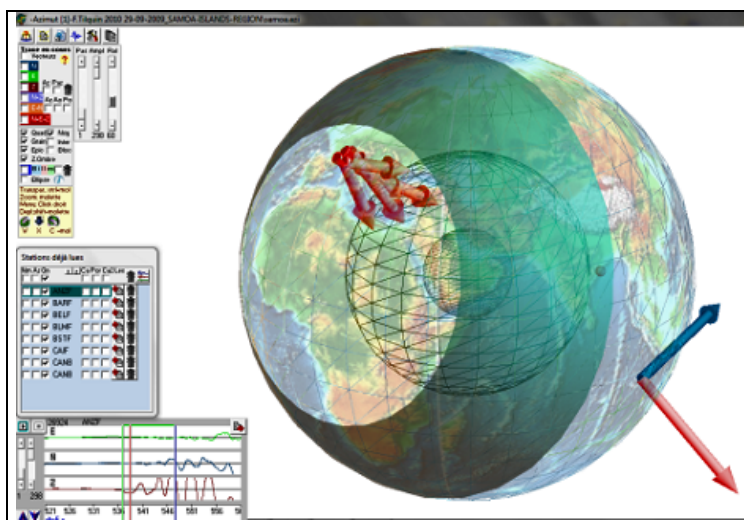




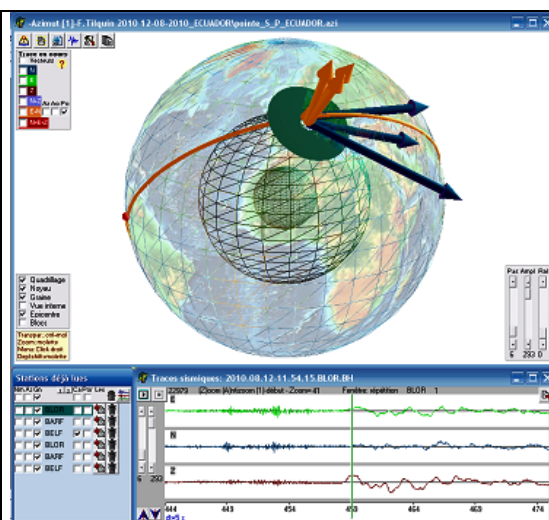
The spring-slider block model experiment in classroom to answer the question: is it possible to predict earthquakes?



An experiment to understand the fault mechanism.



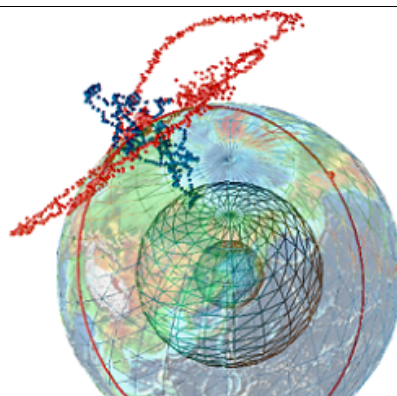
First ground movement: temporary depression (Samoa)



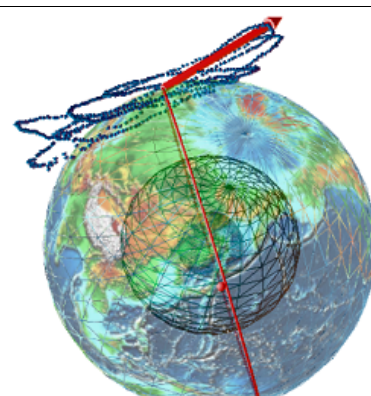
Perpendicularity of P-wave and S-wave.  
1st arc pointed.



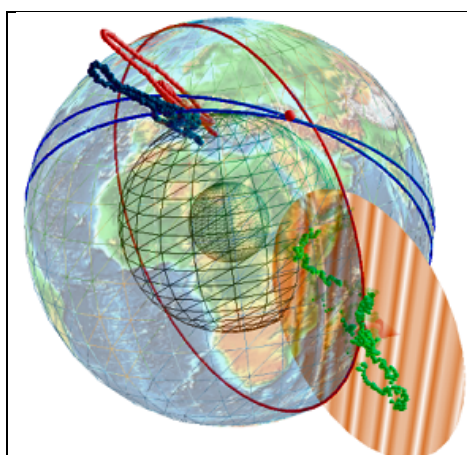
Azimuth and ground compression  
movement : Japon (1st arc)



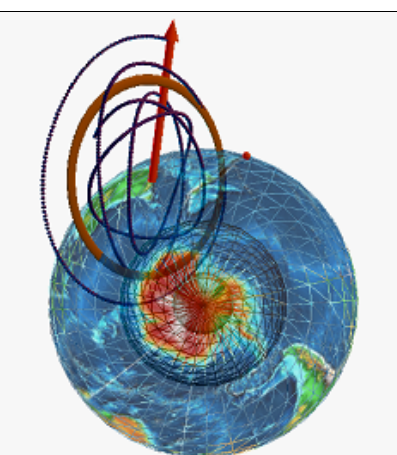
Perpendicularity of P-S  
waves  
(Vector extremity during few  
sec)



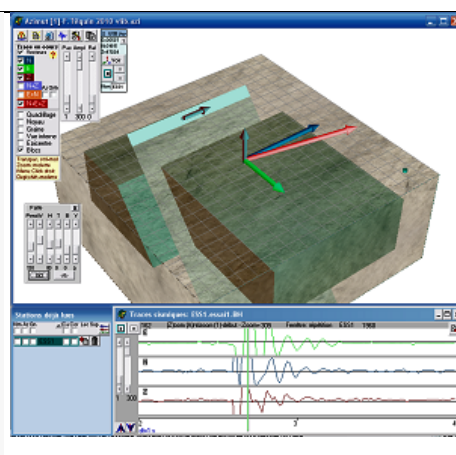
Love wave : S-wave  
horizontal and  
perpendicular to azimuth.



Epicenter determination with 3  
azimuths of P-wave during 10 s.



Ellipticity of Rayleigh wave  
(P-wave perpendic with  
surface and azimuthal)



Acquisition of trace from a  
USB accelerometer.

AZIMUT© FT 12/2011 free software (Lycée Marie Curie- Echirolles Académie de GRENOBLE). The software shows the 3D ground movements from the 3 components earthquake stations.



## **GERARDO CARRASCO NUÑEZ**

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### **I. ACADEMIC FORMATION**

1. *Bachelor* 1980-1985 *Geologist Engineer*. Engineering Faculty, (U.N.A.M.).
2. *Master in Engineering* 1984-1988, U.N.A.M.
3. *Ph. D. degree* 1989-1993. (Volcanology). Michigan Technological University, U.S.A..

### **II. CURRENT POSITION**

*Director, Center of Geosciences*. Campus U.N.A.M. Juriquilla, Qro., México.

*Researcher, tenure position*. Center of Geosciences, Campus U.N.A.M. Juriquilla, Qro., México.

*Professor of Volcanology. Graduate Earth Sciences Program*, U.N.A.M., Masters level.

*Adjunct professor at Northern Arizona University*, Flagstaff, USA, since 2003.

### **III. PAST POSITIONS & SPECIAL DISTINCTIONS**

- 1993-1997 Earth Sciences Graduate Program, UNAM (Chair for geology Section)
- 2003-2006 Academic Secretary of the Center of Geosciences, UNAM
- 2007 Visiting Professor (sabbatical semester) at Leicester University, U.K.
- National Researcher (CONACYT), Level **III** (2015-2019) and level **D** of Academic performance (PRIDE), UNAM. Fellowship reward.
- Member of the Scientific Committee of Popocatepetl volcano, since 1994.
- *Member of the Mexican Scientific Academy*.
- *Associated editor of the Geological Society of America (2013-2015)*

### **IV. AWARDS**

- *Gabino Barrera Medal*. Best student of geology 1979-83. Geologist Engineer. Engineering Faculty, U.N.A.M.
- Honors (*Mención Honorífica*) for outstanding performance on bachelor thesis "Estudio Geológico del Volcán Popocatepetl".
- *High Performance Certificate (Diploma de Aprovechamiento)*. Best grade average of geologist engineer 1979-83.

- *"Overseas travel fund (for young scientists)"*, International Association of Chemistry of Earth's Interiors (IAVCEI) to attend the meeting in 1993, Canberra, Australia.
- *Civil Merit Award (Premio al Mérito Civil)*. Award provided by the Puebla State Government during the volcanic crisis of Popocatepetl volcano in December, 1994.

## **V. ORGANIZING EVENTS**

- 1997 Organizing Committee of IAVCEI General Assembly in Puerto Vallarta, Mexico
- 2007 Organizing Committee for 2007 American Geophysical Union Joint Meeting in Acapulco, Mexico (Volcanology section).
- 2014 Chair of the Organizing Committee of the 5<sup>th</sup> International Maar Conference. Queretaro, Mexico. A IAVCEI congress.
- 2016 Member of the International Scientific Committee of the 6<sup>th</sup> International Maar Conference. Changchun, China.

## **VI. RESEARCH INTEREST:**

I am particularly interested on active volcanism, hazard assessment and explosive volcanism. Also, I am interested on transport mechanism and eruptive processes in pyroclastic flows, lahars, debris avalanches and lava flows. Geothermal exploration and evolution of large andesitic stratovolcanoes, including processes of collapse, instability and petrological issues, as well as some other subjects. Geo-medicine research.

## **VII. TEACHING COURSES**

- Optical Mineralogy, Igneous Petrology, Field geology and Volcanology for undergraduate students. Engineering Faculty, U.N.A.M. 1983-1989.
- Igneous Petrology, Volcanic Hazards, Volcanology and Pyroclastic rocks for Graduate students at Graduate Program in Earth Sciences, UNAM. 1993- present

## **VIII. STUDENT ADVISEES**

- Undergraduate: 12      Graduate: 9 (Masters) and 4 (Ph. D.)

## **IX. PUBLICATIONS**

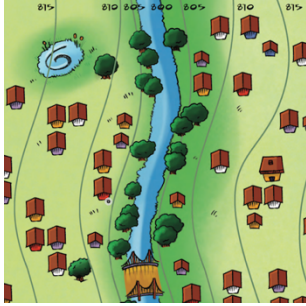
- |                                 |                           |
|---------------------------------|---------------------------|
| A) Scientific papers: 53        | B) Chapters in books: 8   |
| C) Maps: 4 (2 volcanic hazards) | D) Extended abstracts: 16 |
| E) Citations: 900               | F) H Index 13             |



**RECENT VOLCANISM AND HAZARDS OF A  
NATURAL LABORATORY AT THE EASTERN MEXICAN VOLCANIC BELT**

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Mexico is known as a land of volcanoes. Colima and Popocatepetl are by far the most active volcanoes in Mexico, belonging to the Mexican Volcanic Belt (EMVB) that cover the Central part of the country from coast to coast. The eastern sector of this geological province is considered as a wonderful natural laboratory for volcanology because it includes a great diversity of volcanoes, with different compositions, eruptive styles and products. The volcanic activity occurred from late Pleistocene to the Holocene, and represents different types of hazards, even though only one volcano is historically active (Citlaltépetl). This area contains very contrasting volcanoes ranging from large composite volcanoes such as Citlaltépetl (Pico de Orizaba), Las Cumbres, and Cofre de Perote, and a large caldera (Los Hornos) as well as other smaller volcanoes including viscous lava domes, hydrovolcanic volcanoes (maars) and cinder cones. Even though some volcanoes are currently inactive, they represent an important hazard due to their instability conditions that promoted great landslides in the past, without any precursory volcanic activity. In the past, cataclysmic explosive activity occurred producing voluminous pyroclastic successions and caldera-rim effusions at Los Hornos caldera supervolcano, which at present is an active geothermal field. Monogenetic volcanic fields comprising cinder cones, domes and maar volcanoes include some examples such as El Volcancillo cinder cone that erupted discrete lava flows in prehistoric times. A very interesting vitrophyric rhyolite dome (Cerro Pizarro) shows an unusual polygenetic behaviour with long periods of repose suggesting the potential reactivation in the future. Other interesting volcanoes known as maar volcanoes were produced as a result of extraordinary explosive eruptions when the ascending magma encounters groundwater. Examples of this special volcanism are: Atexcac (a classic basaltic maar), Cerro Pinto (a rhyolitic tuff ring-dome complex), and Tecuitlapa (a basaltic maar with an evident vent migration) maar volcanoes, some erupted during the Holocene (Alchichica), indicating a potential eruptive activity in the future around that area. The EMVB is a volcanically active area where there are many different types of volcanoes, each representing distinct volcanic hazard.

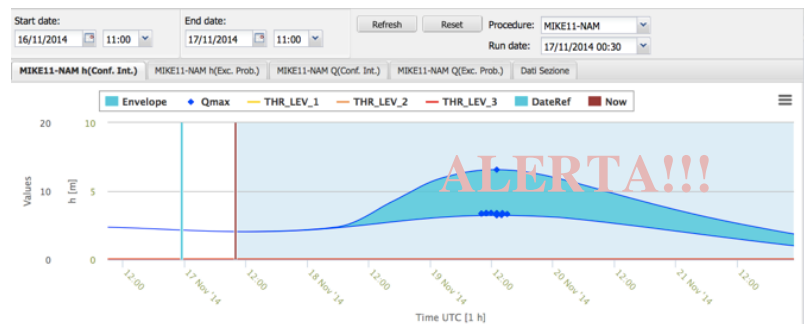


### Where we can expect a flood

How to know if we live in an area at risk of flooding? How often do we have to expect a flood in the area where we live? We will try to explain the concept of return period and the how to draw in a simple way a flood risk map to see if you are at risk or not

### When a flood is coming

How floods are managed to have the least possible damage? The value of historical information and memory. Structural flood protection with levees and dams. Early warning systems and their operation.



### During and after a flood

How to protect yourself from a flood? The emergency plan concept.

We will learn how to observe the precursors of a dangerous situation in order to reach safety in time and what people should never do if the situation is critical for flood risk.

What can we do at home? We'll see how you can prepare a contingency plan for your house and what is needed to survive (action pack). Unfortunately, a catastrophe, a

flood, happened. What the experts do? What can I do?

### References and teaching materials

Discover FLOODS – Kids in Discover Series - Joint development of WMO and “Project WET: Water Education for Teachers”. In English

[http://www.apfm.info/education/kids/WET\\_Discover\\_Floods\\_KIDs.pdf](http://www.apfm.info/education/kids/WET_Discover_Floods_KIDs.pdf)

Discover FLOODS – Educators Guide - Joint development of WMO and “Project WET: Water Education for Teachers”

[http://www.apfm.info/education/kids/WET\\_Discover\\_Floods\\_Ed\\_Guide.pdf](http://www.apfm.info/education/kids/WET_Discover_Floods_Ed_Guide.pdf)

READY FLOODS – Kids in Discover Series - Developed by U.S. FEMA – In Spanish

<http://www.ready.gov/kids/know-the-facts/floods>





**Xyoli Pérez-Campos**  
*Mexican Geophysical Union*

She graduated as Geophysical Engineering at the School of Engineering, UNAM, the National Autonomous University of Mexico. She got her master's in statistics and master's and Ph.D. in seismology from Stanford University. She continued with a postdoc at Caltech, where she also spent her sabbatical year in 2011-2012. Currently, she is a researcher at the Institute of Geophysics, the head of the National Seismological Service, the President of the Mexican Geophysical Union and a member of the Scientific Advisory Committee of the National Civil Protection System on natural hazards due to geological phenomena.

# SEISMIC HAZARDS IN MEXICO

Xyoli Pérez-Campos, Mexican Geophysical Union

## Earthquake Hazards in Mexico

Mexico is a seismic prone country. Every day, the National Seismological Service reports in average 36 earthquakes. Most of them are smaller than magnitude 4.0. In general, the Pacific coast is the region where more and larger earthquakes occur (Figure 1); this is due to the interaction of the Cocos and the Northamerican plate. These large earthquakes can affect the center and the coast of the country. However, other important earthquakes have been reported inland. They have not been too large, but they have occurred close to populated urban areas, producing important effects. Knowing and characterizing all seismic sources is essential for evaluating the seismic hazards of certain place.

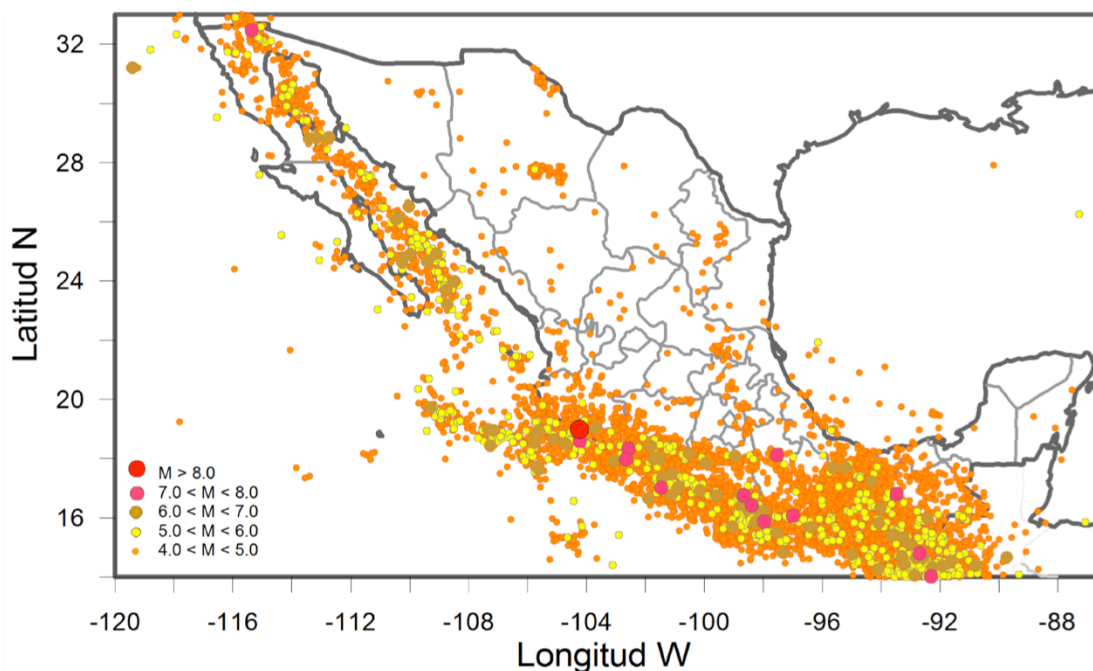


Figure 1. Earthquakes, magnitude larger or equal to 4.0, reported by the National Seismological Service (SSN) since 1974. They mostly occur at plate interactions; however, some intraplate seismicity is evident. Figure generated by the SSN.

## Xyoli Pérez-Campos

She graduated as Geophysical Engineering from the honors program of the School of Engineering, UNAM, the National Autonomous University of Mexico. She got her master's in Statistics and master's and Ph.D. in Geophysics from Stanford University. She continued with a postdoc at Caltech, where she also spent her sabbatical year in 2011-2012. Currently, she is a researcher at the Institute of Geophysics, UNAM, professor at the School of Engineering, the head of the National Seismological Service, the President of the Mexican Geophysical Union and a member of the Scientific Advisory Committee of the National Civil Protection System on natural hazards due to geological phenomena.

Selected papers:

1. UNAM Seismology Group, Papanao, México earthquake if 18 April 2014 (Mw7.2), *Geofisica Internacional*, **54**(4), 363-386, 2015.

2. Singh, S.K., J.F. Pacheco, X. Pérez-Campos, M. Ordaz, E. Reinoso, The 6 September 1997 (Mw4.5) Coatzacoalcos-Minatitlan, Veracruz, Mexico earthquake: implications for tectonics and seismic hazard of the region, *Geofísica Internacional*, **54**(3), 289-298, 2015.
3. Singh, S. K., M. Ordaz, X. Pérez-Campos y A. Iglesias, Intralab versus Interplate Earthquakes as Recorded in Mexico City: Implications for Seismic Hazard, *Earthquake Spectra*, **31**(2), 795-812, doi: 10.1193/110612EQS324M, 2015.
4. Singh, S.K., X. Pérez-Campos, V.H. Espíndola, V. M. Cruz-Atienza, y A. Iglesias, Intralab earthquake of 16 June 2013 (Mw5.9), one of the closest such events to Mexico City, *Seismol. Res. Lett.*, **85**, 268-277, doi: 10.1785/0220130179, 2014.
5. Pérez-Campos, X., D. Melgar, S. K. Singh, V. Cruz-Atienza, A. Iglesias, V. Hjörleifsdóttir, Rapid estimation of fault parameters for tsunami warning along the Mexican subduction zone: A scenario earthquake in the Guerrero seismic gap, *Seismol. Res. Lett.*, **84**(3), 474-484, doi: 10.1785/0220120156, 2013.
6. UNAM Seismology Group, Ometepe-Pinotepa Nacional, Mexico Earthquake of 20 March 2012 (Mw7.5): A Preliminary Report, *Geofísica Internacional*, **52**(2), 173-196, 2013.
7. Singh, S. K., X. Pérez-Campos, A. Iglesias, D. Melgar, A Method for Rapid Estimation of Moment Magnitude for Early Tsunami Warning Based on Coastal GPS Networks, *Seismol. Res. Lett.*, **83**(3), 516-530, 2012.
8. UNAM Seismogy Group, Intralab Mexican earthquakes of 27 April 2009 (Mw5.8) and 22 May 2009 (Mw5.6): a source and ground motion study, *Geofísica Internacional*, **49**(3), 153-163, 2010.
9. Singh, S. K., M. Ordaz, J. F. Pacheco, L. Alcántara, A. Iglesias, S. Alcocer, D. García, X. Pérez-Campos, C. Valdes, y D. Almora, A Report on the Atoyac, Mexico, Earthquake of 13 April 2007 (Mw 5.9), *Seismol. Res. Lett.*, **78**(6), 635-648, 2007.
10. Pérez-Campos, X., J. McGuire y G. C. Beroza, Resolution of the slow earthquake/high apparent stress paradox for oceanic transform fault earthquakes, *J. Geophys. Res.*, **108**, B9, 2444, doi:10.1029/2002JB002312, 2003.
11. Pérez-Campos, X., S. K. Singh y G. C. Beroza, Reconciling regional and teleseismic estimates of seismic energy, *Bull. Seism. Soc. Am.*, **93**, 2123-2130, 2003.
12. Pérez-Campos, X., y G. C. Beroza, An apparent mechanism dependence of radiated seismic energy, *J. Geophys. Res.*, **106**, 11,127-11,136, 2001.

## **Peligro sísmico en México**

México es un país con un potencial sísmico alto. Cada día, el Servicio Sismológico Nacional reporta en promedio 36 sismos. La mayoría de ellos tienen magnitudes menores de 4.0. En general, la costa del Pacífico es donde se presentan con mayor frecuencia y donde ocurren los sismos más grandes (Figura 1); esto se debe a la interacción de las placas de Cocos y Norteamérica. Estos sismos grandes pueden afectar a ciudades importantes del centro y de la costa del país. Sin embargo, también se han reportado sismos importantes en el centro del territorio nacional. Su tamaño no ha sido muy grande; pero su cercanía a centros urbanos ha provocado efectos importantes en ellos. El conocer y caracterizar todas las fuentes sísmicas posibles es esencial para evaluar el peligro sísmico al que se encuentra sujeto un lugar.

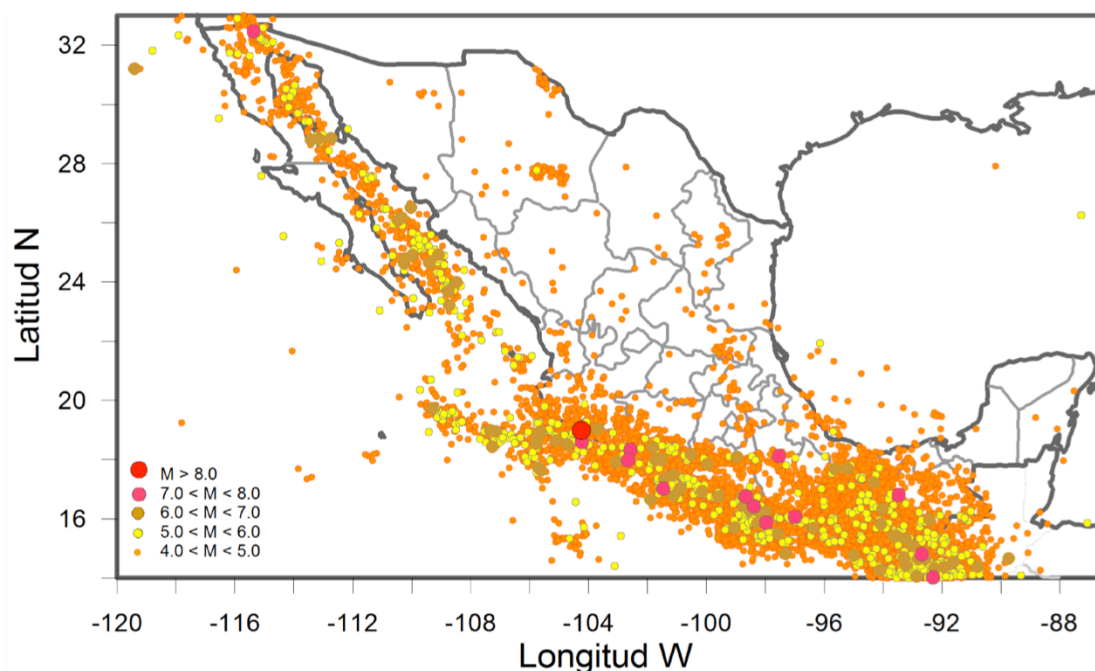


Figura 1. Sismos de magnitud mayor o igual que 4.0, reportados por el Servicio Sismológico Nacional (SSN) desde 1974. La mayoría de ellos ocurre en la interacción entre las placas tectónicas; sin embargo, es también evidente la presencia de sismicidad intraplaca. Figura generada por el SSN.

### Xyoli Pérez Campos

Se tituló como ingeniera geofísica del Programa de Alto Rendimiento Académico de la Facultad de Ingeniería de la Universidad Nacional Autónoma de México (UNAM). Obtuvo su maestría en Estadística y su maestría y doctorado en Geofísica de la Universidad de Stanford. Continuó con su posdoctorado en el Instituto Tecnológico de California (Caltech), donde también realizó una estancia sabática en 2011-2012. Actualmente es investigadora en el Instituto de Geofísica de la UNAM, profesora de la Facultad de Ingeniería de la UNAM, jefa del Servicio Sismológico Nacional, Presidenta de la Unión Geofísica Mexicana y miembro del Comité Científico Asesor del Sistema Nacional de Protección Civil en amenazas naturales por fenómenos geológicos.

#### Publicaciones seleccionadas:

13. UNAM Seismology Group, Papanao, México earthquake if 18 April 2014 (Mw7.2), *Geofísica Internacional*, **54**(4), 363-386, 2015.
14. Singh, S.K., J.F. Pacheco, X. Pérez-Campos, M. Ordaz, E. Reinoso, The 6 September 1997 (Mw4.5) Coatzacoalcos-Minatitlan, Veracruz, Mexico earthquake: implications for tectonics and seismic hazard of the region, *Geofísica Internacional*, **54**(3), 289-298, 2015.
15. Singh, S. K., M. Ordaz, X. Pérez-Campos y A. Iglesias, Intralab versus Interplate Earthquakes as Recorded in Mexico City: Implications for Seismic Hazard, *Earthquake Spectra*, **31**(2), 795-812, doi: 10.1193/110612EQS324M, 2015.
16. Singh, S.K., X. Pérez-Campos, V.H. Espíndola, V. M. Cruz-Atienza, y A. Iglesias, Intralab earthquake of 16 June 2013 (Mw5.9), one of the closest such events to Mexico City, *Seismol. Res. Lett.*, **85**, 268-277, doi: 10.1785/0220130179, 2014.
17. Pérez-Campos, X., D. Melgar, S. K. Singh, V. Cruz-Atienza, A. Iglesias, V. Hjörleifsdóttir, Rapid estimation of fault parameters for tsunami warning along the Mexican subduction zone: A scenario

earthquake in the Guerrero seismic gap, *Seismol. Res. Lett.*, **84**(3), 474-484, doi: 10.1785/0220120156, 2013.

18. UNAM Seismology Group, Ometepec-Pinotepa Nacional, Mexico Earthquake of 20 March 2012 (Mw7.5): A Preliminary Report, *Geofísica Internacional*, **52**(2), 173-196, 2013.
19. Singh, S. K., X. Pérez-Campos, A. Iglesias, D. Melgar, A Method for Rapid Estimation of Moment Magnitude for Early Tsunami Warning Based on Coastal GPS Networks, *Seismol. Res. Lett.*, **83**(3), 516-530, 2012.
20. UNAM Seismology Group, Intralab Mexican earthquakes of 27 April 2009 (Mw5.8) and 22 May 2009 (Mw5.6): a source and ground motion study, *Geofísica Internacional*, **49**(3), 153-163, 2010.
21. Singh, S. K., M. Ordaz, J. F. Pacheco, L. Alcántara, A. Iglesias, S. Alcocer, D. García, X. Pérez-Campos, C. Valdes, y D. Almora, A Report on the Atoyac, Mexico, Earthquake of 13 April 2007 (Mw 5.9), *Seismol. Res. Lett.*, **78**(6), 635-648, 2007.
22. Pérez-Campos, X., J. McGuire y G. C. Beroza, Resolution of the slow earthquake/high apparent stress paradox for oceanic transform fault earthquakes, *J. Geophys. Res.*; **108**, B9, 2444, doi:10.1029/2002JB002312, 2003.
23. Pérez-Campos, X., S. K. Singh y G. C. Beroza, Reconciling regional and teleseismic estimates of seismic energy, *Bull. Seism. Soc. Am.*; **93**, 2123-2130, 2003.
24. Pérez-Campos, X., y G. C. Beroza, An apparent mechanism dependence of radiated seismic energy, *J. Geophys. Res.*; **106**, 11,127-11,136, 2001.



**Jaime Urrutia-Fucugauchi**  
Mexican Academy of Sciences

Professor of Geophysics at the National University of Mexico (UNAM) Institute of Geophysics, Mexico City. Ph.D. School of Physics, University of Newcastle upon Tyne, UK 1980.

Areas of interest include paleomagnetism, stratigraphy, impact craters, gravity, tectonics, natural hazards and paleoclimates. In the last years, interest has been focused on the Chicxulub impact, the Cretaceous/Paleogene boundary, mass extinctions and paleoclimates. Cooperation studies have been conducted with colleagues from various countries including USA, United Kingdom, Japan, Spain, Canada, Brazil, Chile, Argentina, France, Germany, Italy, India and Thailand.

President of Mexican Academy of Sciences 2014-2017; Member of El Colegio Nacional, UNAM Board of Directors and UNAM Foundation. President Mexican Physics Society 2013-2015. International Secretary American Geophysical Union 2006-2010. Director Institute of Geophysics UNAM 1997-2005. Secretary-Treasurer Mexican Academy of Sciences 2004-2006, President Mexican Union for Quaternary Studies 2002-2008, President Mexican Geophysical Union 1986-1988, President National Committees International Lithosphere Program and International Year of Planet Earth, Chairman AGU Latin-American RAC 1991-1994, Program chair for the AGU 2007 & 2013 Joint Assemblies, member AGU Governance Committee 2010-2014 and Governing Board of American Institute of Physics. Thesis advisor for 45 postgraduate students. Coauthored 220 refereed publications. Edited special volumes for Tectonophysics, Physics of the Earth and Planetary Interiors, Quaternary International, Geofísica Internacional and Meteoritics and Planetary Science and the Cambridge book on Extreme Natural Hazards, Disaster Risks and Societal Implications. Associate Editor Journal Geophysical Research 1993-1995, Bulletin Geological Society of America 1999-2001, Quaternary Research 2005-, Geofísica Internacional 1994-, Geologica Acta 2002- and Revista Mexicana Ciencias Geológicas 2002-. Awards: American Geophysical Union International Award 2013, National Medal Sciences and Arts 2009, Geological Society of America Fellow 2010, National University 2007, TWAS Fellow 2004, Mexican Academy of Sciences Award 1991, American States Organization Noriega Award 1992, Mexican Geophysical Union Maldonado Award 1992, National Puebla Award 1988.

# **GEOPHYSICAL STUDIES IN ACTIVE VOLCANOES**

**Jaime Urrutia Fucugauchi**

Mexican Academy of Sciences

Studies on volcanic hazards and volcano monitoring techniques have intensified with development of improved observational techniques and mitigation programs. Study of volcanoes undergoing eruptive phases present major challenges, related to access restrictions, security issues, measurement precision, identification of eruption precursors, documentation of volcano structure, deep processes and installation of monitoring systems. Advances in methods, instrumentation, computing, data storage, telecommunications, satellite observation systems, interferometric synthetic aperture radar (InSAR), global positioning systems (GPS), use of large number high density monitoring arrays, borehole instrumentation, gas emission analyses and aerogeophysical surveys are providing increased understanding of magmatic and eruption processes (e.g., Francis and Rothery, 2000; Dzurisin, 2003; McNutt, 2005; Smith et al., 2009).

Hazard and risk analyses of stratovolcanoes present particular challenges. Stratovolcanoes are characterized by long periods of inactivity, with relatively low level fumarolic, seismic and deformation activity, making difficult to forecast reawakening episodes resulting in large explosive eruptions (Smith et al., 2009). This has been exemplified by the eruptions of Mount St. Helens in the Cascades, western USA (1980), El Chichon volcano in southern Mexico (1982) and Pinatubo volcano in the Philippines (1991). Explosive eruptions pose major hazards associated with flank collapses, debris avalanches and eruption-triggered lahars such as those generated in the 1985 Nevado del Ruiz eruption in Colombia. Analysis of volcanic hazards and implementation of volcano monitoring networks constitute major components of hazard prevention and mitigation programs.

Progress in studying active volcanoes, with implementation of systematic monitoring programs, has been slow partly because it is difficult to investigate the deep structure of volcanoes where magmatic processes take place and to detect reliably the unrest which would lead to an eruptive event. Eruptive activity is triggered and controlled by magmatic processes at depth, with ascent of magma, fracturing, pressure-temperature changes, degassing and magma interactions within the conduit system. High resolution imaging of underground structure, conduit systems and understanding of magma-rock interactions, magma ascent, degassing, eruption triggering and eruption dynamics belong to these major areas of research. Aerogeophysical surveys are being successfully applied to investigate the underground structure of volcanoes and volcanic terrains (e.g., Fedi et al., 1998; Finn et al., 2001; De Ritis et al., 2010; Nakatsuka et al., 2009), offering advantages as compared to ground based techniques. Potential field and electromagnetic methods developed and



used from helicopter and aircraft platforms provide accurate information for risk analysis and complement ground based monitoring networks.

In this presentation, we focus on geophysical methods applied to study and monitor active volcanoes, hydrothermally altered zones, underground structure, faults and fractures and thermal and magma movement effects. Case studies are presented using ground magnetic and aeromagnetic surveys, repeat magnetic surveys and paleomagnetic and rock magnetic analyses. Gravity surveys investigate mass distributions characterized by density contrasts in the volcanic edifices, magma conduits and deep structures. Magnetic surveys detect magnetization and magnetic susceptibility contrasts of underground structures. Airborne magnetic, gravity and electromagnetic methods use high resolution data acquisition systems, GPS positioning, accurate processing, InSAR, topographic corrections and forward and inverse modeling techniques to define the geometry and characteristics of volcanic structures and active systems.

Few volcanoes in Mexico are monitored with enough spatial and temporal resolution to investigate long-term processes involved in magma generation and ascent, which poses problems for volcanic risk analyses and short- and long-term forecasting.

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## **Giorgio Boni**

Prof.

University of Genova, CIMA Research Foundation

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### **EDUCATION**

Doctorate degree in hydrodynamics - University of Padua, Padua, Italy (02-1994 to 07-1997)

Laurea degree in Civil Engineering - University of Genoa, Genoa, Italy (10-1987 to 12-1992)

### **CAREER**

- October 1998 – October 1999

University of Genoa. Technical assistant. Implementation and development of a monitoring and early warning system for the establishment of the Regional Hydro-Meteorological Centre (Liguria-Italy)

- November 1999 – October 2000

University of Genoa. Technical officer: Coordination of the activities of the University of Genoa in the framework

of the EU project INTERREG IIC “management of the territory and flood prevention”

- November 2000 – present University of Genoa. Assistant Professor. Vice-president of the Environmental Engineering Course, Coordinator

of international relations for the courses related to Environmental Engineering, Coordination of several research projects.

- October 2007 – July 2012

CIMA Research Foundation. Scientific director

- July 2012 – present CIMA Research Foundation. Consultancy for the development of research and technology transfer activities in the

field of remote sensing applications to hydrometeorology and hydroclimatology.

- April 2015 - present

President of the Natural Hazard Division of the European Geosciences Union.

- November 2015

WMO expert at the workshop on the advances made in the framework of PRONACCH and PRONACOSE projects organized by CONAGUA and WMO, Mexico City (Mexico).

### **RESEARCH INTERESTS**

Hydro-meteorological and eco-hydrological applications of remote sensing techniques.

Hydrological and hydraulic modelling for flood forecast.

Statistical analysis of hydro-meteorological extremes

Operational Emergency Management Services.

### **PUBLICATIONS AND SERVICES**

- Boni, G., L. Pulvirenti, F. Silvestro, G. Squicciarino, P. Pagliara, R. Onori, C. Proietti, L. Candela, A. R.

Pisani, S. Zoffoli, Flood Mapping by Italian Civil protection, in CEOS Satellite Earth Observations In Support Of Disaster Risk Reduction, Special 2015 WCDRR Edition, Part II, Case Studies, Ivan Petiteville, Stephen Ward, George Dyke, Matthew Steventon & Jennifer Harry Eds., pp. 20-23, 2015,

<http://ceos.org/home-2/eohandbook2015/>

- Boni, G. and F. Siccardi, Scenes and Scenarios: Managing natural disasters by using satellite images to their full potential, Public Service Review: European Science & Technology, 10,128-129, 2011

- Boni, G., Observe to Predict, Predict to Prevent: Cooperation and Technology Transfer between Science and Public Administrations for Civil Protection, Public Service Review: European Science & Technology, 8,194-195, 2010

### **AWARDS AND HONORS**

National Research Council (Italy). CNR-MIT Research Grant. Research activity on data assimilation for hydrological applications.

# DISCOVER FLOODS

## Suggestions to educate kids and young to flood prevention

**Giorgio Boni**

EGU Natural Hazard Division President

CIMA Research Foundation

*(In cooperation with World Meteorological Organization, APFM-WET Project)*

The purpose of this presentation is to provide the elements on technical arguments as well as on possible teaching methods for training young people.

The goal is to empower young people to understand what is a flood and how to protect themselves and help others to protect themselves from the risk of flooding.

We will try together to answer several relevant questions.

### What is a flood?

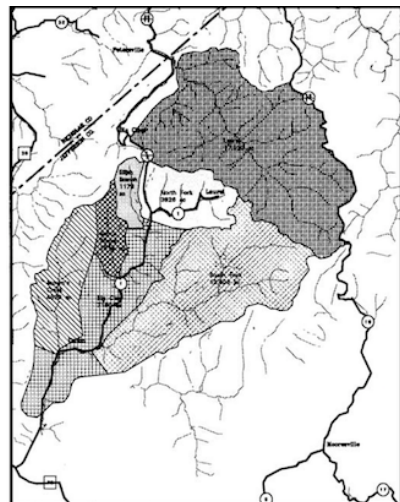
How floods form. We'll see what is the hydrological. Understand the quantity of water and the processes that play relevant roles in flood formation.

### Color me a watershed

What is a watershed and how can we read a map to identify the river basins. What is discharge, what is a hydrograph and what information can give us. How discharge is observed and how to draw a hydrograph.

### When a flood comes and how

We will try to understand when rain can generate or not a flood, and because sometimes the flood comes quickly and sometimes takes days to get there and to dry up, and then how, if we live near a river, to figure out what kind of phenomenon we should expect





**David Alberto Salas de León**  
*University of San Luis Potosi*

Physicist by the Autonomous University of San Luis Potosi, PhD in Oceanology by the State University of Liege in Belgium obtained with the greatest distinction in the thesis defense. Fulltime Researcher at the Marine Sciences and Limnology Institute, UNAM (ICML). Member of the National System of Researchers of Mexico Level II. He was Head of the Physics Department of the Marine Science Unit of the Autonomous University of Baja California, now Faculty of Marine Sciences; Coordinator of the Postgraduate Program in Marine Sciences of UNAM; editor of the Annals of ICML and Head of Academic Computing Service ICML; representative for Mexico to TEMA (Program of the Intergovernmental Oceanographic Commission of UNESCO to promote the teaching of Marine Sciences). He has produced 83 scientific articles, 78 research reports, has been invited to give lectures in scientific and non-scientific forums 34 times and has participated in 98 scientific conferences, he has advised 14 thesis in bachelor, 17 MSc and 4 PhD. He was representative of Mexico to the IAPSO (International Committee for the Study of Physics of the Oceans Union of the Geodesy and Geophysics Association), to the World Global Climate Change Program and the International Program for the IOC-UNESCO Group for the Study of Deep Oceans Mix. He is evaluator of scientific programs and projects for the CONACYT of Mexico, for the CONICYT of Colombia, for the National Polytechnic Institute of Mexico, for the Autonomous Metropolitan University of Mexico, UNAM, the Ministry of Foreign Affairs of Mexico, and CONICET of Argentina. He is member of the portfolio of arbitrators and has reviewed manuscripts for: Journal of Geophysical Research, Nature, Journal of Marine Systems, Marine Science, Proceedings of ICML, Geophysics, Latinamerican Journal of Geophysics, Atmosphere, Marine Research CICIMAR, Hydrobiology, Continental Shelf Research and FES-Z Magazine UNAM. He is editor in chief of the Open Journal of Marine Science and member of scientific societies: Mexican Mathematic Society, Mexican Physics Society, American Geophysical Union and Mexican Geophysical Union. His research interests are on ocean processes modeling, the study of long waves and physics-biology interactions in the oceans. He has received two special awards for videos of science divulgation in the Crystal Display Presentation: The UNAM Oceanographic Buoy (2005) and Searching the Juncal (2013) and the Prize for the best Scientific Research by the Autonomous Metropolitan University in 2005.

# TSUNAMIS

**David Alberto Salas de León**  
**University of San Luis Potosi**

Tsunamis are natural phenomena that have affected humans throughout history, understanding the origin and behavior of these phenomena help to develop programs and strategies to be better prepared to face them and reduce damages and losses they cause. Tsunami are a natural phenomenon that can happen at any latitude and longitude of the planet; however, the Pacific Ocean is where occur most frequently (Table 1). Note that in the Caribbean Sea has presented 13.8% of tsunamis recorded until 2005.

Table 1. Percentage distribution of tsunamis in the oceans and seas of the world (Bryant, 2005).

Region	Percentage
Est Coast of the Atlantic	1.6
West Coast of the Atlantic	0.4
Mediterranean	10.1
Bengala Bay	0.8
East India	20.3
South West Pacific Coast	25.4
Japan-Russia	18.6
East Pacific Coast	8.9
Caribbean Sea	13.8

In the six years following the devastating earthquake that caused the tsunami in the Indian Ocean in 2004, which caused the loss of 220,000 people, five tsunamis have occurred in which at least 1,400 people have lost their lives, 664 in Java tsunami of 2006, 54 people in the Solomon Islands tsunami of 2007, 191 people in Samoa tsunami of 2009, 124 people in Chile tsunami of 2010 and 431 people in the tsunami in Indonesia 2010. In addition to human losses, tsunami have material losses estimated at billions of dollars due to the floods affecting residential areas, schools, hospitals, industries, businesses, agricultural land, etc. Mexico has been affected by tsunamis more than once, so the study of the origin, evolution and impact of tsunamis in Mexico is an important issue.

A tsunami is a wave or a train of waves, generated by an abrupt vertical displacement of large scale in the water column in a certain region of the ocean or waterbody. The word tsunami comes from the Japanese language meaning "harbor wave" because such waves often develop a resonance phenomenon in ports after earthquakes.

Tsunamis can be produced by: volcanic explosions; from 92 documented cases of tsunamis generated by volcanoes, 16.5% were associated with tectonic tremors, 20% with pyroclastic material that hit the ocean, 14% with underwater eruptions, 7% with the collapse of the volcano and the rest by other factors. Other factor that generate tsunamis is the landslide above or below water as occurred on July 17 of 1998 in Papua New Guinea, the Lituya Bay in Alaska that generated a flood wave of more than 100 m high, and the landslide in Juan de Grijalva Chiapas occurred on November 4 of 2007. Asteroid impacts also generate tsunamis, an example of this is the Chicxulub occurred in the Gulf of Mexico 65 million years ago. Tsunamis caused by meteorological events or meteotsunamis, are common in mid latitudes (between the tropics and polar regions), where variations in atmospheric pressure are big along the time, such phenomena tend to occur in lakes and bays where the resonance wave is present. Another phenomenon that produce



Tsunamis is seismic activity; lthough most tsunamis are caused by underwater seismic disturbances, from a total of 15,000 earthquakes between 1861 and 1948 only 124 tsunamis were recorded, this low frequency suggests that most tsunamis have a small amplitude and are almost unnoticeable or that earthquakes only generate tsunamis when seismic wave magnitude is greater than 6.5 on the Richter scale.

The way that tsunamis are classified is considering how long it takes to arrive to the coast or the distance from the origin place of the tsunami to the coast where arrives. The tsunami is classified as: local tsunamis, regional tsunamis and long distance tsunamis. In local tsunamis the place of arrival to the coast is very near or within the generation area (area bounded by the displacement of the seabed) in this case the arrival time of the tsunami is less than an hour; an example is the tsunami generated by an earthquake in the Middle America Trench front of Michoacan on September 19 of 1985, it took only 30 seconds to arrive to Lazaro Cardenas Port and 23 minutes to Acapulco. In regional tsunamis the coast is no more than 1,000 km away or a few hours from the area of generation, for example, the tsunami caused by the earthquake occurred in the coast of Colombia on December 12 of 1979, which took 4 hours to arrive to Acapulco. Long distance Tsunamis (remote, transpacific or teletsunamis), the arrival site is very remote; more than 1,000 km away from the area of generation; it means about half a day or more of travel one example is the tsunami occurred after the earthquake in Chile on May 22 of 1960, that took 13 hours to reach Ensenada (Mexico) another example is the tsunami generated in Japan on May 16 of 1968 that took 14 hours to arrive to Manzanillo (Mexico).

The Tsunamis can be described with four physical parameters: wavelength, period, velocity and amplitude. Typical values for these parameters in a tsunami are: a wavelength that is between 10 and 500 km, a period between 100 and 2000 s (1.6 min and 33 min) and heights at deep sea or offshore of few centimeters which increase as the tsunami approaches the coast, this period waves can travel at a speed of 600 km h<sup>-1</sup> to 900 km h<sup>-1</sup> (166 m s<sup>-1</sup> to 250 m s<sup>-1</sup>).

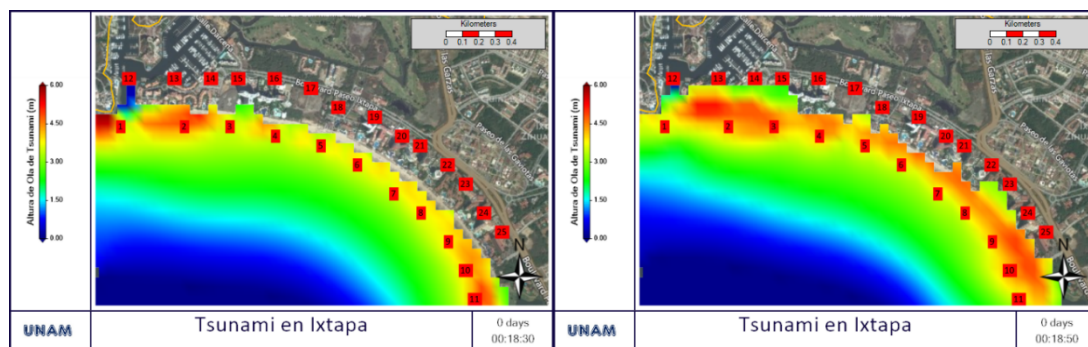


Figure 1. Sequence of flooding caused by a hypothetical tsunami in Ixtapa, Guerrero, Mexico. Images every 20 min.



**Dr. Zenon Medina-Cetina**  
*Texas A&M University TAMU*

Dr. Medina-Cetina is Associate Professor in the Zachry Department of Civil Engineering and in the Harold Vance Department of Petroleum Engineering (Joint Appointment) at Texas A&M University TAMU, where he leads the Stochastic Geomechanics Laboratory SGL (2008 - Present). He is a Civil Engineer from the Universidad Autonoma de Yucatan UADY Mexico (Soil Dynamics, 1994), and a Master of Engineering from the Universidad Nacional Autonoma de Mexico UNAM (Geostatistics, 1996). Dr. Medina-Cetina obtained a Masters of Science and a Philosophy Doctorate at The Johns Hopkins University (Stochastic Mechanics, 2001- 2006).

Dr. Medina-Cetina held a dual appointment at the Norwegian Geotechnical Institute NGI in Oslo Norway (2006 - 2008), in the International Centre for Geohazards ICG and in the Computational Geomechanics Division CGD. His research and consulting interests include System's Mapping of Risk, Reliability and Sensibility Analysis; Probabilistic Site Characterization; and Uncertainty Quantification of Multi-Physics Geomechanical Processes.

At SGL-TAMU Dr. Media-Cetina leads the Yucatan Initiative Project, the largest TAMU faculty-driven international collaboration with Mexico, including research, academic and service projects in Engineering, Ggeosciences, and Agriculture and Life Sciences, aimed to build knowledge-based economic development strategies for the States of Texas and Yucatan. He is also a member of the Adivsory Committee of TAMU's Center for Geospatial Sciences Applications and Technology GEOSAT, TAMU's largest faculty-driven Center, aimed as fostering collaborations among all TAMU scientific and technologifcal disciplines working in geospatial applications.

Dr. Medina-Cetina was elected twice Chair of the Offshore Site Investigation and Geotechnics Committee OSIG of the Society for Underwater Technology SUT , where under his leadership set OSIG's Vision and Mission, while working together with some of the most recognized leaders in Geology, Geophysics, Geotechnical Engineering, Geomatics, Metocean, and Marine Archaeology in the USA. For his effort, he was voted SUT Fellow. After stepping down as Chair of SUT-OSIG, Dr. Medina-Cetina was elected President SUT-Houston, where he currently leads technical commitees for Offshore Site Characterization, Subsea Engineering and Operations, Renewables and Climate Change.

# **USE OF COMPUTATIONAL PARTICLE MECHANICS TO SIMULATE THE IMPACT THAT CREATED THE CHICXULUB CRATER IN YUCATAN**

Zenon Medina-Cetina<sup>1</sup>, Tam Duong<sup>2</sup> and Jaime Urrutia-Fucugauchi<sup>3</sup>

This work introduces the use of computational particle mechanics theory to simulate the impact that created what is known today as the Chicxulub Crater in the State of Yucatan Mexico. Computational particle mechanics is an emerging field of study that allows to discretize mass media into particles (from atoms to full geologic formations), where the interaction between particles is subjected to simple Newtonian physics. This simplicity when extrapolated to millions of particles interacting between each other to represent realistic geologic bondings require an optimal use of computational resources to be able to propagate force actions induced into the mass media.

Site investigations conducted outside and inside the footprint of the Chicxulub crater have produced key characteristics of the geologic formation in the region of the impact. This information is currently used by multiple research teams to characterize the geomechanical properties and the geomorphology of the geologic formation before and after the impact. A forward model using computational particle mechanics is presented in this work, which resembles the geological and geomechanical characteristics at the site of impact, and which simulates the impact for various unknown conditions, such as the diameter of the impacting mass, its velocity, and other numerical conditions associated to the model's boundary effects, and constitutive geomechanical characteristics.

Results presented in this work include a parametric analysis to better understand the proper selection of initial, boundary, and loading (impact force) conditions, as well as the selection of the proper material characteristics and its spatio-temporal inter-relations required to produce the 'after the impact' geologic and geomechanical characteristics that matches current site observations. To achieve this goal, multiple combinations of the model conditions and material characteristics can lead to the same site conditions. This is known as a mechanical ill-posed problem.

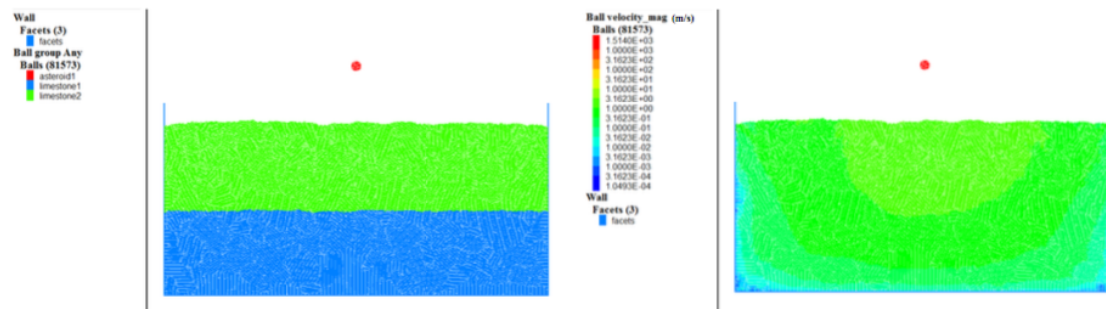
The collaboration between the UNAM and TAMU teams, aim at solving this problem, by providing in the next stage of this research, a probabilistic approach to search for the likely combinations of the model conditions and material properties (non-unique) that may have produced the impact characteristics observed today at the Chicxulub Crater.

Below it is included on the left column, a two geologic sequence of limestone is presented before and during the impact, identifying the source of each body. The right column, shows the corresponding velocities at the same time steps of the impact sequence. The general characteristics of the model comparing to the real condition are

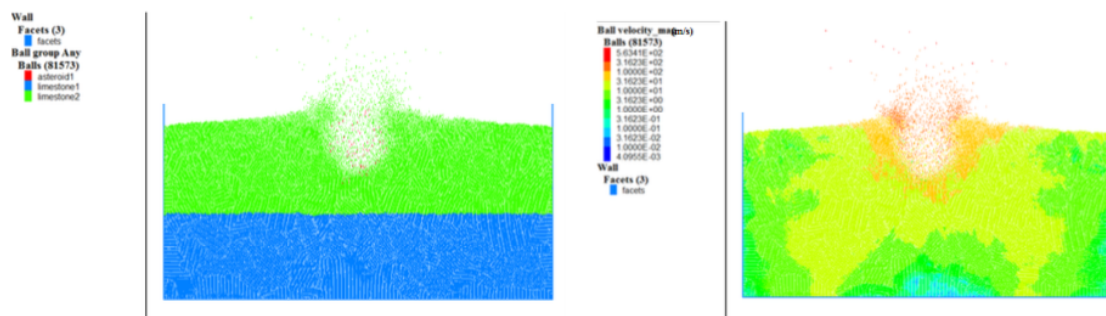
as follows: 1) The scale ratio of the model to the real site is 1/100; which the model container size W 4000m x H 2000m is approx. W 400km x H 200km in real condition; 2) Each particle radius is 5 m.; 3) The asteroid velocity is assumed to be 1,500 m/s; 4) The model soil type is assumed to be limestone in 2 layers which the top layer has a stiffness ratio of 1/10 the bottom layer.

<sup>1</sup> Texas A&M University <sup>2</sup> Texas A&M University  
<sup>3</sup> Universidad Nacional Autonoma de Mexico

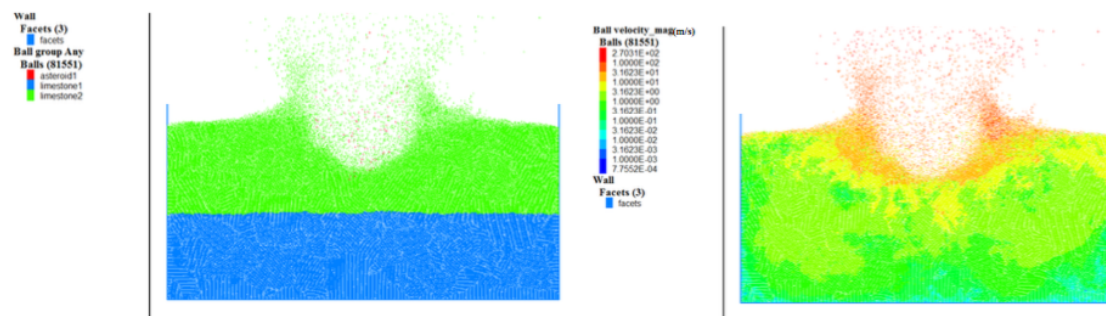
Before impact



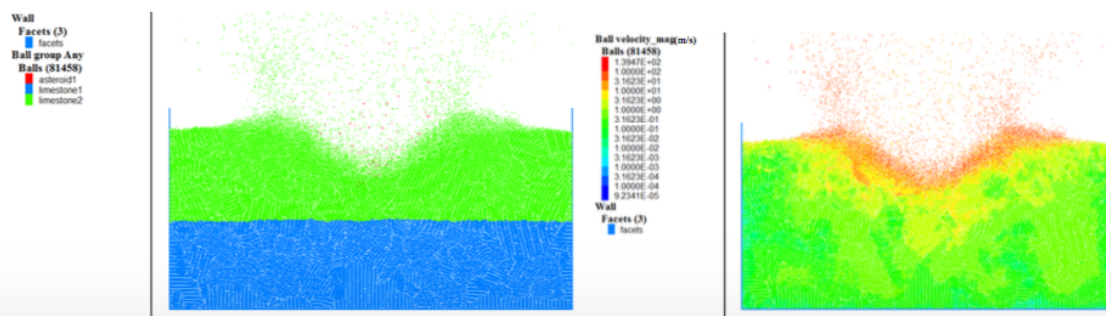
During impact at 20,000 calculation cycles



During impact at 40,000 calculation cycles



During impact at 60,000 calculation cycles





**Alaniz Álvarez Susana Alicia**

Centro de Geociencias

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**Position**

Senior researcher, Centro de Geociencias UNAM, Campus Juriquilla

**Education**

- 1988: Engineering degree in Geology (UNAM, México) –Structural Geology and Petrology of Metamorphic rocks.
- 1996: PHD in Earth Sciences: Thesis “Age, kinematics and tectonic implication of the deformation events in the Oaxaca fault, southern Mexico”

**Research interest**

- Cenozoic tectonics of northern Mexico and their relationships with the Basin and Range of North America.
- Experimental and theoretical studies about deformation along different cortical levels.
- Magmatic, metamorphic and sedimentary process related with major faults.
- Science education in elementary school

**Teaching experience**

Structural Geology, Universidad Nacional Autónoma de México. 1997-present.

Introduction to Geosciences for teachers of elementary schools.

Secretaría de Educación de Guanajuato, 2009-present.

USEBEQ, Education Secretary of the state of Querétaro. 2009-2010.

**Bibliometry**

44 scientific articles listed in Scopus. Total Citations: 550.

Since 2007, I dedicate a significant part of my activities in promote the important of science in basic education.



# COMMUNICATING SCIENCE THROUGH HUMOR, DOES IT WORK?

Susana A. Alaniz Álvarez

Centro de Geociencias

Universidad Nacional Autónoma de México

Internet has become an excellent platform to distribute educational material, mainly by videos, e.g., Coursera, Youtube, TedEd, Slide share, etc. The purpose of this workshop is to investigate the science achievement with a video that includes humor. It has been documented that humor enhances interest and attention; the links between incongruities with communication seem that could enhance the higher-order cognition necessary to learn science; also the humor contributes to break the passive participation in class, and reduces the student stress. On the other hand, there are some considerations against humor in class; for example, the humor is most common in youngest children than in adults and many scientists believe that science should be considered seriousness because it requires deep thinking.

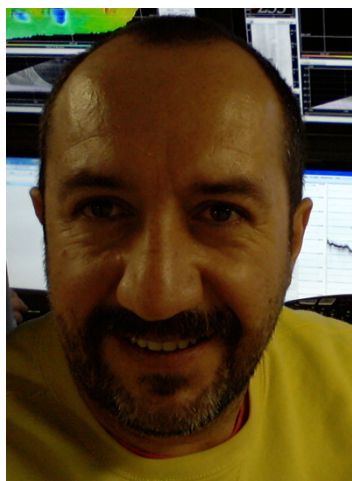
A quasi-experimental method was followed to investigate humor in teaching and learning science in elementary education. For our study, we choose the Continental Drift as a scientific target because it involve many concepts of Physics, Earth sciences, Chemistry and Biology. How do the continents move? It is a question that has been discussed in the scientific community for more than a hundred years ever since Alfred Wegener proposed the Pangea supercontinent in his book “The origin of continents and oceans”.

We used the video “A la Deriva” (<https://www.youtube.com/watch?v=bH0b4z0vc58>) which was performed by professional clown-technique director and actors, it is 30 minutes long, and the script was based on the text of “¡Eureka! Continents and Oceans are floating” ([http://www.geociencias.unam.mx/geociencias/experimentos/serie/libro3\\_arquimides.pdf](http://www.geociencias.unam.mx/geociencias/experimentos/serie/libro3_arquimides.pdf)). The video is divided in 6 sections: Pangea, density, viscosity, isostasy, heat transfer and conclusion. In order to know if the video is a potential tool for science learning, we design an evaluation instrument that consists of questions about four cognitive abilities: definition, classification, evaluate scientific evidence, and use of scientific knowledge in daily activities.

Participants were 60 students divided into two groups of sixth grade; the grade was chosen because the plate tectonics theory is included in the curricular program. The first group saw the video “A la Deriva” with relevant humor, and the second group had a traditional class with the same information but with no humor. Surprisingly, the results indicate no significant difference in student achievement between the two groups ( $p > 0.05$ ). The traditional method works slightly better for defining concepts and classifications, and the achievement of students with both methods is almost the same for evaluation of scientific evidence and for using the scientific knowledge in daily activities.

In this workshop, the teachers will evaluate their previous knowledge about continental drift with a questionnaire; then, they will watch the video “A la Deriva” which will be projected, and later they will respond the same questionnaire from the beginning. Each teacher will evaluate their own conceptual understanding after the video with the normalized gain (g). A month after this workshop, we will send to the teachers a different questionnaire in order to evaluate the retention of the concepts related with the information provided in this workshop.





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**1. FORMACIÓN ACADÉMICA:**

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1.1.1 Carrera y Duración: Licenciatura en Oceanología, cinco años

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Título Obtenido: Licenciatura en Oceanología

Fecha de Examen: 19 de Marzo de 1991

Nombre de la tesis: Evolución geológica y estructural de la diatomita de San Felipe, B.C.

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**1.2 ESTUDIOS DE POSGRADO:**

1.2.1 Especialidad y fechas: Maestría en Sismología

Institución: Centro de Investigación Científica y Educación Superior de Ensenada

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Fecha de examen: 14 de diciembre de 1994

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Director: Dr. Arturo Martín Barajas y M. en C. Francisco Suárez Vidal

Calificación: Aprobado

1.2.2 Especialidad y fechas: Doctorado en Física del Interior de la Tierra

Institución: Instituto de Geofísica, UNAM

Grado obtenido: Doctor en Física del Interior de la Tierra

Fecha de examen: 13 de marzo de 2002

Título de la tesis: Magnetoestratigrafía y paleomagnetismo del cráter de Chicxulub, Yucatán, México

Director: Dr. Jaime Urrutia Fucugauchi

Calificación: Mención Honorífica. Medalla Alfonso Caso, al graduado más distinguido de la generación 2002

1.2.3 Especialidad y fechas: Groundwater Exploration, exploitation and management.

Institución: Universidad Hebrea de Jerusalén

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**2. EXPERIENCIA PROFESIONAL:**

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1. Profesor-Investigador Titular B, de tiempo completo, Centro de Investigación Científica de Yucatán, A.C., a partir de 16 de mayo de 2011 a la fecha.

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3. Profesor-Investigador Asociado C, Centro de Investigación Científica de Yucatán, A.C., 16 de mayo de 2004 al 15 de mayo de 2007.

4. Estancia Post-doctoral Laboratoire des Sciences du Climat et de l'Environnement, Unité Mixte de Recherche CNRS-CEA, Gif-sur-Yvette, Francia. Octubre 2002 a Abril 2004.

5. Estancia Post-doctoral, Instituto de Geofísica, UNAM, Marzo 2002 a Septiembre 2002.

6. Asistente de Investigador de la Dra. Joann Stock, California Institute of Technology, Abril a Julio, 1997.

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1. Profesor de Geología General, posgrado en Ciencias del Agua, Centro de Investigación Científica de Yucatán, A.C., 2015 a la fecha.

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5. Profesor de Física en el Curso de Introducción a las Ciencias de la Salud, Escuela de Medicina, Universidad Anáhuac, Campus Norte, 2000.

6. Instructor de laboratorio de topografía, Facultad de Ciencias Marinas, U.A.B.C., 1997

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# THE VULNERABILITY OF A KARSTIC AQUIFER

## LA VULNERABILIDAD DE UN ACUÍFERO KÁRSTICO

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### RESUMEN:

Debido a las características kársticas del acuífero costero del norte de Yucatán, éste presenta una alta heterogeneidad. Una de las técnicas más utilizadas, es utilizar un modelo de tres capas, con la finalidad de simplificar la estructura vertical del acuífero. Sin embargo, es importante señalar que, si bien el modelo de tres capas, para sondeos eléctricos verticales en 1-D, funciona gracias al alto contraste de resistividades entre las calizas saturadas con agua dulce y de mar, éste no resuelve las heterogeneidades laterales. Es por ello que en este trabajo presentamos los resultados de la investigación de la estructura del acuífero en la zona de transición entre la zona continental el manglar en la zona del puerto de Sisal, Yucatán. Los resultados, en principio, definen bien la estructura vertical del acuífero en la zona continental, sin embargo, en la zona de manglar, la estructura se presenta mucho mas homogénea y, por lo tanto, complicada. En primera instancia, una de las observaciones más importantes a resaltar en este trabajo, es la dificultad técnica al utilizar métodos eléctricos en terrenos donde la litología, per se, presenta altas resistividades como la caliza ( $>8,000 \Omega \cdot m$ ), lo cual respresenta que un alto porcentaje de la corriente inyectada no penetrará a las profundidades esperadas; lo anterior significa que las profundidad de investigación, en estas condiciones, se ve seriamente comprometida. En particular, en este estudio, de los 60 m de profundidad de investigación teóricos, concluimos que sólo los primeros 15 m son confiables. No obstante lo anterior, los resultados obtenidos nos permitieron comprobar que la estuctura lateral del acuífero es sumamente complicada y que, ésta, en la zona de manglar está controlada por la estructura radical de la vegetación y la tasa

### ABSTRACT

The karstic nature of the coastal aquifer of Northern Yucatan, presents a high heterogeneity. One of the most used techniques to characterise it is to use a three layers model, aim to simplify the vertical complexity of the aquifer. However, it is important to note that, if the three layers models serves well for geoelectrival 1D, thanks to the resistivity contrasts between the freshwater and marine saturated limestones, this model does not resolve lateral heterogeneities. That is the reason we used the geoelectrical multielectrode tomography technique, to resolve lateral heterogeneities. In this contribution we show the results of a survey conducted in the transition zone from the continental zone to the mangrove zone in the Port of Sisal, Yucatan. The results, in principle, defined well the structure of the continental aquifer, however, within the mangrove, the results showed a more homogeneous and, therefore, more complicated structure. One very important observation is that, considering the lithology of the area, the complications araised from a high resistivity of the surficial dry limestone ( $>8,000 \Omega \cdot m$ ), that prevents the injection of the projected current into the ground, compromising the actual depth of investigation. In particular, in our study, from the expected 60 m of depth of investigation, we concluded that only the first 15 m are within statistical significance. Nonetheless, we were able to model the stratified aquifer withing the continental zone and to conclude that the aquifer, within the mangrove, is controlled by the roots of the mangrove and the sedimentation rates controlled by the vegetation.

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**1989-2000 Researcher and Senior Researcher**

Istituto Nazionale di Geofisica (ING from 1989, then INGV from 1999)

**1988 Fellowship**

U.S. Geological Survey, Menlo Park, CA.

**Main Activities**

Seismic and tsunami monitoring; Seismotectonics, stress maps; Seismic tomography and crustal-mantle structure studies, fault zones and volcanoes; Studies of earthquakes sequences; Science communication and social implication of earthquakes

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Sapienza University, Rome, Italy

**PERSONAL SKILLS****Languages**

- Italian Mother tongue
- Good English
- Good French

**Communication skills**

- Good interpersonal skills gained through experience as responsible of the National Earthquake Centre and as project coordinator
- Experienced in contacts with media (TV, radio, newspapers, blogs)

- Active in the social media platform INGVterremoti for science communication

### **Organisational/manageriale skills**

- Director of the Italian National Earthquake Centre of INGV (2001-2004; 2004-2007; 2012-2013), managing the seismic surveillance of Italy, responsible for monitoring networks.
- Member of the Italian National High Risk Committee – Commissione Nazionale Grandi Rischi (2000- 2004)
- Member of the Scientific Council of the Italian National Group of Volcanology (Gruppo Nazionale di Vulcanologia) from 1998 to 2001
- Member of the High Risk Commission (Commissione nazionale Grandi Rischi) of the Prime Minister Council from 2001 to 2004
- Participant in the National Committee of the Prime Minister Office for the preparation of the seismic Hazard map of Italy (2002-2003)
- Coordinator (co-chair) of WP2 (“Geophysical data”) in the framework of NEAMTWS (Northern Atlantic and Mediterranean Tsunami Warning System) dell’UNESCO from 2005 to 2007
- INGV representative of the “Paritetic Commission” in the Agreement between national Civil Protection Department – DPC and INGV (2007-2013)
- Responsible of the Activity Line T5 (Seismic surveillance and Emergency operations) for the Earthquake Department of INGV (2014-present)

### **Job related skills**

- Coordination of technological and scientific teams ▪Referee for several Geophysical journals
- Shifts in the H24 control room of INGV Centro Nazionale Terremoti for seismic monitoring of Italy since 1989, for tsunamis from 2014, and as Senior Seismologist on-call from 2000.
- Active participation in seismic field experiments and emergencies from 1988.

### **Main projects**

- Responsible of Unit “Seismic Tomography” in the Project "Deep Structure of the Ross Sea region, Antarctica” of the Italian National Project of Antarctica research - PNRA (Progetto Nazionale di Ricerche in Antartide) 1993-1996
- Principal Investigator of the European Project “GeoModAp (Geodynamic Modelling of an active region of the Mediterranean: the Apennines)” (EV5V-CT94-0464) 1994-1997
- Principal Investigator of the National Project “Probable Earthquakes in Italy between 2000 and 2030” “Terremoti Probabili in Italia tra il 2000 e il 2030: elementi per determinare le priorità per la riduzione del rischio sismico" 1999-2003
- Responsible of Research Unit UR3 of Project FIRB-MIUR (Minister of university and Research) “Airplane”: Piattaforma di ricerca multidisciplinare su terremoti e vulcani” 2007-2010

# **GEOPHYSICAL AND SOCIAL ASPECTS OF EARTHQUAKES IN ITALY: FROM L'AQUILA 2009 TO AMATRICE 2016**

**Alessandro Amato**

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with contributions by Andrea Cerase

Italy is a seismic country, and a densely populated region. Although there are not huge earthquakes as in the circum-Pacific subduction zones, an earthquake of magnitude ~6 strikes the region approximately every 5 years causing damages and casualties. The last of these earthquakes occurred on August 24, 2016 in central Italy, resulting in several villages strongly damaged or even destroyed, with a death toll of nearly 300 people. Previous earthquakes with fatalities occurred in 2012 in Po Plain (northern Italy), in 2009 in L'Aquila (central Italy), 2002 in Molise (southern Italy), 1997 in Umbria-Marche (central Italy). In addition, several  $M \sim 7$  earthquakes occurred in many seismic areas of Italy in the past centuries, with thousands or even tens of thousands victims each. The main reasons for such a heavy death toll are the shallow hypocentral depths (generally less than 10-15 km), and the high vulnerability of buildings in old towns and villages. It is estimated that about 70% of existing buildings in Italy are not seismically safe.

The 2016 earthquake occurred during the night between August 23 and 24, when people were sleeping. The earthquake ruptured on a very shallow fault, cutting the crust beneath the Apennines for a length of 25 kilometers and a width of about 10, with a magnitude 6. Like most of the earthquakes occurring on the Apennines, it had a normal faulting mechanism, which results from the general extension affecting the backbone of the Italian peninsula.

The town of Amatrice, a village where many people from Rome and other towns use to spend their holidays during the summer, was destroyed by the seismic waves in a few seconds, and paid the heaviest death toll. The small town is located at the southern tip of the fault and received a strong shaking. Amatrice was first classified as a seismic zone more than one century ago, after the 1915 "Avezzano" earthquake, and therefore the extreme vulnerability of so many buildings surprised many of us. Seismic engineers described several cases of poor materials used for construction, poor building techniques, in some cases they found interventions that worsened the buildings' response to seismic shaking. On the opposite side of the fault, 30 km to the North, the town of Norcia withstood well the strong shaking, with almost no collapse and no fatalities.

The social response to the impending seismic risk was quite different in two little cities, both facing strong earthquakes ( $M > 5.5$ ) in their seismic history. The concept of preparedness could resume such a difference in buildings and social vulnerability: while the Norcia's inhabitants decided to face future earthquakes by reinforcing their buildings, people from Amatrice underestimated the risk, despite the warnings provided by seismologists, the official INGV seismic hazard map, and the seismic classification that puts the municipality in the first (most dangerous) zone.

The figure shows the seismic histories of the two towns. The main difference is in the time elapsed from the last damaging quake. In the Norcia case it was less than 30 years ago (in 1979), while in the case of Amatrice the last damaging event occurred 300 years ago. This suggests that the "seismic memory" is very important in raising the attention



paid by citizens, authorities, and media towards the problem of seismic risk. The main problems to face in order to achieve an effective seismic risk reduction are 1) a fatalistic inclination towards natural disasters, and 2) the false sense of immunity, as an unjustified certainty that earthquakes will strike elsewhere but not in my own place.

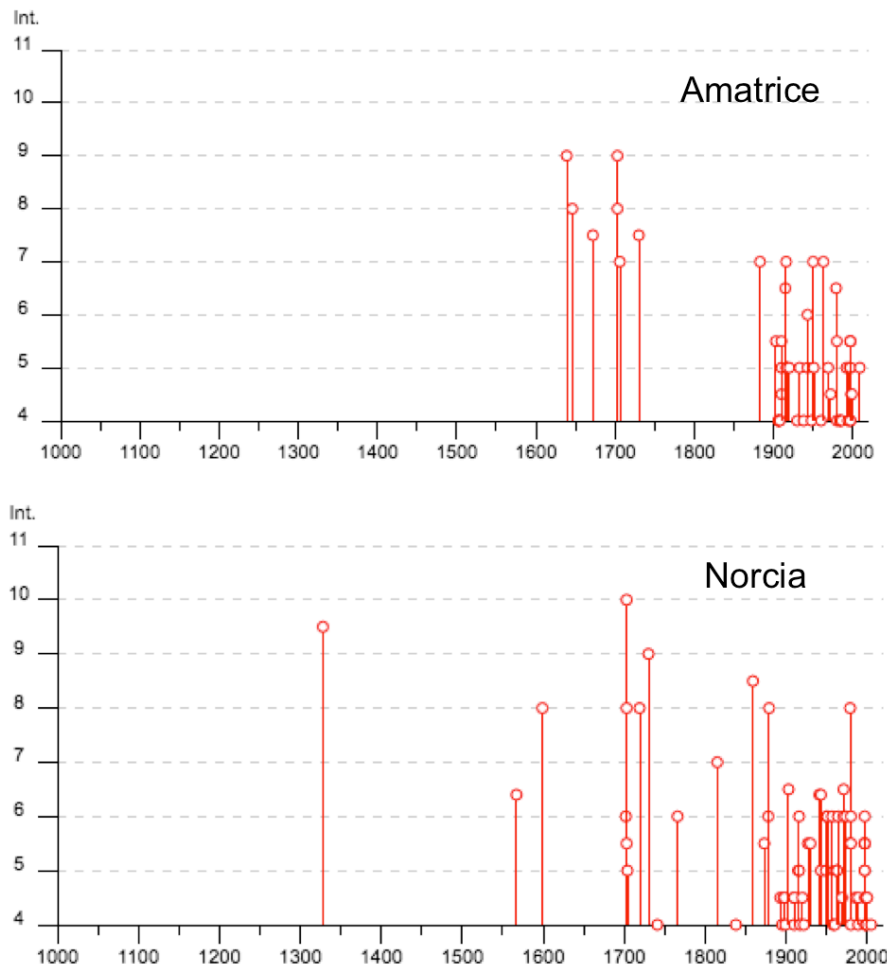


Figure 1. Comparison between the seismic histories of Amatrice (top) and Norcia (bottom). The first town was destroyed by the 2016 earthquake, while Norcia withstood it, thanks to the countermeasures put in place after the 1979 damaging shock.

Only seven years before the 2016 earthquake, another similar shock (M6.2) hit the town of L'Aquila. Although the number of people living on top of the fault in the 2009 earthquake was much higher compared to the 2016 event, the death tolls of the two events are very similar, around 300. As for Amatrice, also in L'Aquila the last damaging earthquake occurred in 1703, more than three centuries before, and the seismic memory was not so fresh.

The 2009 L'Aquila earthquake was followed by a long queue of scientific and social debates, due to a complex situation that was triggered by several facts: a long seismic swarm preceding the main event; someone who claimed to have predicted the event in advance (actually he did not). As for the 2016 event, also in this case the shock occurred during the night, but many people were out of their homes for some M3-4 foreshocks were felt a few hours before. In addition, the local civil protection had released a crazy statement of no future shocks, lately corrected by the national authorities which for this reason convened a meeting of experts in L'Aquila a few days before the earthquake. Just

before the meeting, the vice-head of the national Civil Protection body released a TV interview in which he apparently reassured the population that no strong shocks were expected (or at least this was the message received by some of the citizens). This declaration was received by people with great relief, and together with the facts previously described, determined a situation of social amplification of risk.

After a couple of years, a long and complex criminal trial was held, against the scientists and civil protection officials participating to the meeting. Scientists were accused to have downplayed the risk, releasing wrong and reassuring declarations about future ongoing strong earthquakes. In the first degree all the seven experts were sentenced to 6 years of jail and several other social and economic punishments. After two years, six of them were totally cleared (“no case to answer”), whereas the vice-head of civil protection was found guilty by the Appeal and by the Cassation Court (sentenced to 2 years of jail, but with suspended punishment, sentence published in 2016).

The criminal trials, which have lasted for several years, were accompanied by social conflicts in which the role of scientists was put under serious criticism. Scientists were blamed for having done a bad scientific job, for being enslaved by power, for being useless, and so on. Besides the defendants, the whole category of earthquake scientists, at least those related to the governmental institutions like INGV, were strongly criticized. In the meantime, the attention of people, media, authorities, was focused on marginal issues such as the earthquake predictability, while the issue of prevention, building retrofitting and in general the reduction of vulnerability, was put aside.

In 2010 – 2015 the focus of public debate on earthquakes has progressively moved from seismic risk knowledge and effectiveness of mitigation strategies, to the false promises of earthquake prediction and to the blame game against civil protection and scientific institutions, as triggered by the trial itself.

The end of the trial in 2015, with the acquittal of the scientists, reset some of this. In the meantime, many more efforts of earthquake scientists have been devoted to scientific communication, while cooperation with social scientists has started in order to understand and learn the principles of risk communication.

When the 2016 shock suddenly stroke central Italy again, things followed a different path from 2009. No foreshocks were recorded in the days before the main event, no prediction was claimed (except some ridiculous attempts of posthumous validation), no meetings were convened, no declarations, no attention and fear of people before the shock. Earthquakes are really unpredictable: this was probably the conclusion of citizens, media, authorities. In the early aftermath of this recent earthquake, the attention was focused on the real problem, that is, the extreme vulnerability of buildings in Italy. In the first month after the 2016 earthquake we performed a day-by-day analysis of the media and tried (and are still trying) to feed the discussion on the scientific and social issues of earthquakes. We will present the results of this analysis and the comparison with what happened in 2009 and in other cases.