Meeting of the Parliamentary and Scientific Committee on Tuesday, 15th June 2010

# VOLCANIC HAZARDS NEAR AND FAR

Professor RSJ Sparks FRS
Department of Earth Sciences,
University of Bristol
Steve.Sparks@bristol.ac.uk

**Volcanoes grabbed the World's attention when ash from a small eruption of the Eyjafjallajokull volcano in Iceland brought Europe's aviation to a standstill for several days in April 2010. Volcanic eruptions are of course spectacular but they can also be killers and the cause of huge economic losses and societal disruption. At least 500 million people live close enough to active volcanoes to be threatened when they erupt. Managing volcanic risk is thus a worldwide problem. Some of the science issues are generic to many natural hazards and environmental issues. This short article explains some of the key science behind assessing volcanic hazards, discusses the problems of uncertainty and use volcanoes to illustrate the challenges to science of forecasting the future for the benefit of society.**

Volcanoes are dangerous and have several ways of causing mayhem and loss of life. Explosions are a major cause of fatalities through the formation of hot flows of volcanic ash and rocks known as pyroclastic flows. These devastating flows can move down the side of a volcano at speeds of 100 to more than 200 kph and it is impossible to survive their direct impact. Pyroclastic flows have been the major cause of death around the world; the entire population of 30,000 people in the city of St Pierre on the Caribbean island of Martinique was wiped ou0t in just a few minutes by a pyroclastic flow in 1902 when Mont Pelée erupted. Another major danger is the volcanic mudflow when large amounts of water are mixed with new volcanic deposits. In 1985 25,000 people lost their lives when the town of Almero, Colombia was buried by a mudflow. Such tragedies can be avoided by careful monitoring of a volcano and timely evacuation.

But volcanic hazards are not just local, as the April Iceland ash crisis demonstrates. Very large eruptions can have regional and global effects. On 15th June 1991 Mount Pinatubo volcano in the Philippines erupted five cubic kilometres (or a billion tonnes) of volcanic ash in a colossal explosion. This was about the biggest eruption of the 20th century. Sulphur dioxide and sulphuric acid pollution spread around the equator within 3 weeks and it took over 2 years for the global atmospheric pollution to dissipate. The pollution was so great that the trend of increasing $CO_2$ in the atmosphere was momentarily halted, there was global cooling and there was significant reduction in ozone over northern Europe. In 1815 an even bigger eruption (6 billion tons of ash) occurred at Tambora volcano in Indonesia and led to "the year without a summer" in 1816. In1783 a

*. . . At least 500 million people live close enough to active volcanoes to be threatened when they erupt. . .*

major lava eruption known as Laki occurred in Iceland lasting 6 months. One third of Icelanders died largely through famine due to the environmental catastrophe and there is compelling evidence that there were tens of thousands of deaths in England and France related to the resulting sulphur pollution and crop failures.

Volcanic eruptions are one of many kinds of natural hazards that include earthquakes, floods, tsunamis, hurricanes, wildfires, droughts and magnetic storms. There is also evidence that disasters due to natural events are increasing mostly as a consequence of global populations growth, globalisation and associated environmental stresses which are increasing vulnerability. There is also a plausible view that global warming may be increasing the incidence of extreme weather events as energy in the Earth's atmosphere increases. There are thus some broader lessons and perspectives that can be learnt from volcanic hazards, emergencies and disasters. Society is increasingly asking science to make predictions about what the future holds and this is an unprecedented challenge. In the case of natural phenomena science is being asked to predict so that Society can reduce or avoid losses.

The eruption of the Soufrière Hills volcano, Montserrat began in 1995 and is still going on. Over 15 years the volcano has erupted over 1 cubic kilometre of magma. Montserrat has a special interest to the UK as an Overseas Dependent Territory and the eruption has so far cost 20 lives and likely well over a billion pounds. A hospital built in the late 1980's in the capital Plymouth was destroyed in 1997 and is somewhat symbolic in that a hazards assessment of the island in the early 1990's recognised the possibility of an eruption and recommended that key infrastructure should not be built in the south of the island where Plymouth is located. During the crisis the island has been kept going by dividing the island into an exclusion zone around the volcano and a safe area in the north. One of the great difficulties in all such mitigation policies which in the case of Montserrat required evacuation, is a boundary between safe and unsafe areas has to be drawn. In a crowded island this is bound to cause tensions and disagreements as in practice the risk decreases smoothly away from the volcano and a decision has to be made about the level of risk that is acceptable. However, peoples risk threshold varies greatly, while governments tend to be risk averse, not wishing to be held to account by allowing people to live in dangerous areas. On Montserrat this issue was addressed by using the best knowledge of volcano science to assess how risk varied and then providing this information to the authorities to decide where the boundary should be placed. Inevitably one family house would be on the right side of the line while a neighbour 100 metres away would be on the wrong side of the line and would have to move.

Drawing lines on maps to demark safe from unsafe zones sounds easy in principle but is difficult in practise especially if the threshold that defines the line is itself hard to estimate and the uncertainties in these estimate are large. This problem is very well illustrated in the recent Icelandic ash emergency. Initially the operational guidelines for response of air traffic control involved avoidance so computer models simply had to forecast where ash would go rather than how much ash there was. However, engine manufacturers announced after a few days of almost complete shut down of European air space that engines would not be compromised if the ash was less than 2 milligrams of ash per cubic metre of air. Forecasting where the atmosphere has concentrations of ash higher than this threshold is much more challenging and requires advances in scientific knowledge and modelling methods.

> . . . global warming may be increasing the incidence of extreme weather events as energy in the Earth's atmosphere increases. . .

Knowledge about the Earth's volcanoes is still surprisingly meagre. There are some volcanoes like Kilauea, Hawaii and Vesuvius in Italy, which are very well monitored with sophisticated instruments that have a good chance of detecting the telltale tiny earthquakes and ground movements that precede an eruption. However many of the Worlds active volcanoes are located in the developing World where scientific resources and instrumentation are limited or even non-existent. An international project called VOGRIPA being co-ordinated at the University of Bristol is developing a global database on volcanic hazards and eruptions, complementing and partnering the Smithsonian Institution in Washington DC.  One of the products of this project is an inventory of the largest explosive eruptions over the last 10,000 years of Earth history. Analysis of these data show that only about 15% of these eruptions are know prior to 2000 years ago. The database can also be analysed to estimate how often extremely large eruptions like Laki in 1783 and Tambora in 1815 occur. Such eruptions are about 100 times larger than the small Icelandic eruptions that caused so much disruption in April. It looks like there is about a 1 in 3 chance of such an eruption in the 21st century. In the modern globalised and interconnected World the economic and societal impacts of such an eruption would be considerable.

We are entering a century of great change and anxiety. Many of the acute problems that humanity faces require the advance and application of science. Natural hazards are one of many examples of the difficulties as the World becomes ever more populated and inter-dependent. There will be many volcanic emergencies in the next few decades and society needs to be better prepared.

# GEM - GLOBAL EARTHQUAKE MODEL

Dr. Rui Pinho, Secretary General
GEM Foundation,
Via Ferrata 1 27100, Pavia, Italy
rui.pinho@globalquakemodel.org

**Over half a million people died in the last decade due to earthquakes and tsunamis, most of these in the developing world, where the risk is increasing due to rapid population growth and urbanization. In particular many of the world's megacities of 10 million inhabitants and more, such as Delhi, Bogota, Jakarta and Lima, are situated in highly seismic active areas. A significant proportion of the world's population is therefore at risk from earthquakes.**

The 2010 Haiti and Chile earthquakes painfully reminded the world of the destructive impact of seismic events: not only in terms of human casualties, but also in terms of social disruption and economic losses. Some earthquakes have caused losses that are higher than the country's annual GDP.

It may be obvious that there is need to reduce this risk. However in many earthquake-prone regions no risk models exist, and even where models do exist, they are often inaccessible due to their proprietary nature or their complex user-interface. Risk mitigation requires accurate, consensual and uniform risk estimates; reliable earthquake risk information.

Such information should be state-of-the-art and compiled in a transparent manner by the community - everyone should be able to contribute and comment - so that it is owned by the public and hence trusted to be used. It should be accessible to all possible stakeholders, cover the entire globe and not only include hazard and risk information, but extend towards the social and economic impact of earthquakes.

GEM, the Global Earthquake Model initiative, aims to do all that. GEM is an internationally sanctioned programme, initiated by the OECD, working at the establishment of an independent, open standard to calculate and communicate earthquake risk around the world. GEM is structured as a public-private partnership and thereby combines the strengths (and objectives) of both the public and the private sector.

The partnership includes a number of authoritative global institutions, such as the World Bank, the OECD, UNESCO and UN's International Strategy for Disaster Reduction, but also the two largest international professional associations in the field: IASPEI (International Association of Seismology and Physics of the Earth's interior) and IAEE (International Association for Earthquake Engineering). There are six private organisations contributing to GEM and currently nine countries have adhered to GEM and discussions with another 15 are ongoing. GEM's partners have ensured over two-thirds of the 35 Million Euro needed for GEM's first five-year programme.

GEM is building a dynamic, modular, flexible and expandable model, plus accompanying software and tools. Implementation of GEM's working programme is based on a combination of global and regional elements, and integrates developments on the forefronts of scientific and engineering knowledge as well as IT processes and infrastructure. It takes five years to build the first working global earthquake model and its accompanying software and tools. The work started in 2009 and at the end of 2013 the first version of a truly global and comprehensive earthquake model will be presented.

In June 2010 the GEM initiative has been able to deliver a proof-of-concept for hazard and risk calculations on a global scale, mainly as a fruit of the collaborative GEM1 pilot project. GEM1 laid the foundations of the model, by critically reviewing the current state-of-the-art, by collecting input data and models and building engines for global calculations. It also included a first User Needs Assessment.

International consortia, involving hundreds of professionals and institutions, are working on the creation of necessary standards, databases and methodologies on a global level. These are the global components of the model and are thus developed by the community for the community. The work on Hazard Global Components has started and will be delivered in 2012. The work on Risk Global Components will start in the fall of 2010 and will be delivered in 2012 and 2013 and the work on the Socio-Economic Global Components will take of in early 2011, with the goal to be finalized in 2013.

Programs are being set-up in many regions of the world as independently run, bottom-up projects, and links are established with ongoing regional programs. Both such programs are defined as GEM Regional Programs and involve a great number of local experts who will use GEM software, will generate local data, will validate the data and standards that were created on a global level and will serve as a starting point for technology transfer in the region. Currently three GEM Regional Programs are operational: in the regions of Europe and the Middle East and a collaboration is ongoing in Central America. Programs are being prepared in Africa, South-Asia, South-East Asia and Oceania, Central Asia, South America, the Caribbean, North-East Asia

There are hundreds of institutions, organizations and individuals involved in GEM that contribute expertise, data or software, participate in global and regional programs, or take part in reviews and public assessments. Participation of individuals and institutions worldwide ensures that the model is owned by the global community and reflects its needs and knowledge.

GEM is going through a continual user-needs assessment effort, to ensure that the software and tools that are being developed meet the needs of users. GEM potential users are broad and have different characteristics. GEM's products will therefore be attuned to the needs of expert users and consumers with a basic knowledge of the subject. Partnerships and an active user-community are the ingredients

. . . GEM's partners have ensured over two-thirds of the 35 Million Euro needed for GEM's first five-year programme. . .

. . . Participation of individuals and institutions worldwide ensures that the model is owned by the global community and reflects its needs and knowledge. . .

that support the initial use of the tools and subsequent adoption of the information the global earthquake model produces, a necessary first step toward awareness and risk mitigating behaviour.

The main output of GEM's first five-year working programme will be the inclusive OpenGEM platform for the calculation and communication of earthquake risk. It will allow basic and expert users to run applications, access seismic risk information on local, national and regional scale, and visualize the latter in maps, curves, tables and export these in compatible formats. Basic users are likely to want to view output produced by the global earthquake model, perhaps that related to the location of their own house. Expert users will be able "plug in" their own data and run their own calculations. Because not everyone will be able to access an internet portal, or would like to run calculations through the internet, a stand-alone OpenGEM software package will be an important derivative.

GEM will however produce more than a platform for risk assessment. Global harmonized databases within the fields of earthquake hazard, vulnerability, exposure and socio-economic impact will be made available, such as a global earthquake consequences database and a global historical seismic catalogue. GEM will also produce best practices and standards related to many aspects of seismic risk assessment, which will help the community to work together under a common framework at a global scale. A community development platform for the computational engine will allow for true open-source and object-oriented development of the GEM risk engine by the community. Programmers and other experts will be able to test, use and further improve GEM's software code. There will be technical reports for the (scientific) community to build upon. Finally technical training programmes /workshops will be held for diffusion of the knowledge on GEM software and use (including application for risk mitigation), especially in less supported and developed areas where risk information is needed most.

# UK EARTHQUAKE ENGINEERING: REDUCING WORLDWIDE DISASTERS

Dr Tiziana Rossetto
Department of Civil, Environmental and Geomatic Engineering, University College London, London WC1E 6BT
t.rossetto@ucl.ac.uk

**Recent statistics show that over the last 40 years the number of disasters, as well as economic losses and people affected by disasters, is increasing *(Munich Re. 2009)*.** Some of the largest losses derive from earthquake events (or earthquake triggered events such as tsunami). Earthquakes affect both developed and developing countries, although distribution of losses greatly varies in the two cases; economic prevailing in the first case, whilst both human and economic losses being important in the second. For example, the 1995 Kobe Earthquake in Japan (magnitude, Ms=7.0) killed 5,420 people but caused US$ 150 billion economic loss whilst the 1972 Managua Earthquake in Nicaragua (magnitude, Ms 6.1) caused 10,000 deaths and US$ 2 billion economic loss; the latter constituting 40% of the country's GNP.

There is no evidence that the number of earthquake events is increasing, so why are disasters more frequent and more severe? Most economic and life losses in earthquakes occur as a direct or indirect consequence of building and infrastructure collapse. Growing urbanisation with accompanied rapid increase of poorly built housing, uncontrolled use of land, overstretched services and high population densities, has increased our vulnerability to earthquake effects and therefore increased the potential for disasters. Therefore although an earthquake is a natural phenomena, the level of losses are largely dependent on human activity and hence it can be misleading to use the term "natural disaster".

"Surely this is a foreign problem! How are these worldwide earthquakes relevant to us in the UK?" We live in an increasingly globalised world where, as recent events have shown, economic troubles in a country elsewhere can have knock-on effects on the UK economy. Furthermore, the loss of production, manufacture or services in an earthquake affected region can impact UK services, imports and exports. For example, the recent Chile 2010 earthquake caused damage to pulp and paper mills that had a knock on effect on the cost of publishing in the UK. Finally, a country's government is often judged on how well it deals with the aftermath of a disaster, with mismanagement often leading to changes in government or political instability. These instabilities in countries where the UK has interests may or may not be desirable. Understanding earthquake risk and developing engineering knowledge to ensure earthquake-safe construction (earthquake engineering) is also important to the insurance and civil engineering industries in the UK, who have markets and bid for construction projects abroad, respectively.

It is also important to recognise that the UK itself has a low but non-negligible level of seismic hazard, as the 2007 Folkestone (magnitude Ml=4.2) and 2008 Market Rasen (magnitude Ml=5.2) events demonstrate *(see Figure 1)*. Although not relevant to the engineering design of ordinary offices or houses, this seismic activity must be taken into account in the design, building and assessment of important facilities. The UK already operates 24 reactors that provide 1/5th of UK energy, and that this number may increase in the future. All new reactors must be designed to be earthquake resistant and existing facilities assessed at regular intervals for compliance with new safety levels and earthquake building standards.

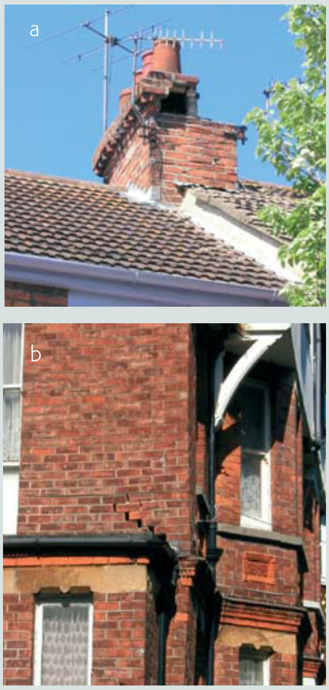
Given the above, it should therefore not be surprising that there is a large amount of Earthquake Engineering expertise in the UK; particularly in the insurance, nuclear, civil engineering consultancy and academic sectors. Numerous examples of iconic structures abroad that have been seismically designed by UK engineers can be found. For example, ARUP carried out the seismic engineering of the 243m tall China Central Television headquarters *(Figure 2a)*, the Beijing National Stadium ("the bird's nest") and Aquatics Centre ("the fish bowl") in Beijing, China. Atkins also did the structural engineering of the second tallest building in Dubai, the Almas tower, which stands at 360m tall and was completed in 2009 *(Figure 2b)*.

Earthquake engineering expertise in academia helps support the competitiveness of UK industry and was recently recognised to be internationally renowned and a strength of UK Research (EPSRC, 2010). Almost all major engineering faculties in UK universities carry out research in earthquake engineering and structural dynamics, with major research centres present in the Universities of Oxford, Cambridge, Bristol, Imperial, UCL, Bath and Sheffield, amongst others. Large scale facilities for experimental testing of structures and soils under earthquakes are available at Oxford and Bristol. The UK also offers 5 MSc programmes on earthquake engineering, out of approximately 20 worldwide. Research from UK institutions has been incorporated in the European building code for Seismic Actions (Eurocode 8) and Earthquake Engineering has a presence in both the Institution of Civil Engineers and Institution of Structural Engineers, through the Society of Earthquake and Civil Engineering Dynamics (SECED) and the Earthquake Engineering Field Investigation Team (EEFIT), respectively. One of the activities of the latter is to investigate the reasons for earthquake damage to structures and infrastructure in global earthquakes and report lessons learned back to the UK community *(e.g. Figure 3)*.

So how can the UK help to reduce worldwide earthquake disasters? Firstly, we can continue to support this discipline and this small but active community to maintain its excellence and place in the worldwide academic and industrial arena. Secondly, we can do more to export some of our knowledge and academic courses to developing countries where knowledge of earthquake engineering principles can have a real impact in saving lives. This can be done through international campuses of UK universities or distance learning methods. Thirdly, I believe we can take Earthquake Engineering to a new level of involvement in International Development (pre-disaster) and reconstruction (post-disaster). This requires facilitation of dialogue between engineers, NGO's, development agencies and other actors to promote sustainable and resilient building in seismic areas. The adoption of "best local practice" and of "opportunity-based" land-use can lead to a promotion of existing weaknesses in buildings and infrastructure. There is a need for international funding and development organisations to ensure that experienced hazard specialists and engineers are co-ordinating or implementing construction projects (either by directly employing them or by ensuring that the contracted work will be lead by such people). This specialist (or team of experts, depending on the number of hazards and scale of the project), should set a framework for the design and construction, which may then be executed by other engineers, builders, workers, etc. after appropriate training and with adequate supervision. Disasters are very complex processes, involving communities as well as buildings. Hence successful involvement in international development requires engineers to break with disciplinary barriers and collaborate with other fields such as architecture, social sciences, psychology etc. This should be supported by a base of interdisciplinary education and research in the field of earthquake engineering, which is already being pioneered at the UCL Earthquake and People Interaction Centre (EPICentre, www.epicentreonline.com), but should be embraced by other institutions also.

In summary, earthquakes are a threat to the world but also an opportunity for UK engineering. The UK has a strong base of expertise in the field of earthquake engineering which is internationally recognised and must be maintained and kept competitive. This short article also proposes some ideas for the promotion of collaborations between earthquake engineering and other disciples to better understand earthquakes, their consequences and aid resilient international development efforts.

**Figure 1**

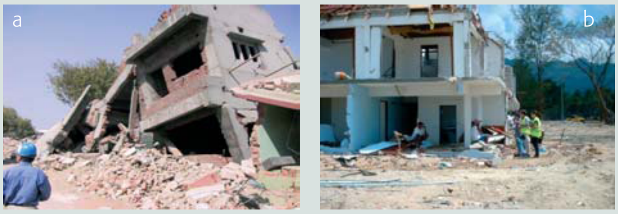


Damage from the 2007 Folkestone earthquake: (a) Damage to a chimney and (b) structural damage, to Victorian masonry houses in Folkestone.

**Figure 2**

The China Central Television headquarters in Beijing, China (a) and the Almas Tower, Dubai (b).

**Figure 3**



Investigation by EEFIT of structural damage due to the 2001 Bhuj India earthquake (a) and 2004 Indian Ocean Tsunami in Thailand (b).

### REFERENCES:

EPSRC (2010). EPSRC Review of UK Academic Research in Ground and Structural Engineering. Engineering and Physical Sciences Council Report.

Munich Re. (2009). Great natural disasters since 1950. Online statistics available at: http://www.munichre.com/en/reinsurance/business/non-life/georisks/natcatservice/long-term_statistics_since_1950/default.aspx