EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol. 23, No. 4 (December, 2019): 309-315

UNIVERSIDAD NACIONAL DE COLOMBIA

GEOLOGICAL HAZARDS

Earthquake predictions and scientific forecast: dangers and opportunities for a technical and anthropological perspective

Edgar Tapia-Hernández[1]*, Elizabeth A. Reddy[2] and Laura J. Oros-Avilés[3]
[1]Department of Materials. Universidad Autónoma Metropolitana - Azcapotzalco, 02200, Mexico City.
[2]Department of Engineering, Design and Society, Colorado School of Mines, United States.
[3]Department of Economics. Universidad Autónoma Metropolitana - Azcapotzalco, 02200, Mexico City
* Corresponding author: etapiah@azc.uam.mx

ABSTRACT

Supporting earthquake risk management with clear seismic communication may necessitate encounters with various popular misapprehensions regarding earthquake prediction. Drawing on technical data as well as insights from anthropology and economics, this paper addresses common and scientifically-unsupported ideas about earthquake prediction, as well as the state of science-based studies regarding statistical forecasting and physical precursors. The authors reflect on documented social and economic effects of unsubstantiated earthquake predictions, and argue that these may be dangerous but may also present certain opportunities for outreach and education in formal and informal settings. This paper is written in light of the importance that the United Nations Office for Disaster Risk Reduction has placed on coordination and communication within and among diverse organizations and agencies as well as by the recent popularity of so-called earthquake prediction in Mexico.

Keywords: Earthquake; prediction; prevention; risk reduction.

Predicciones y pronósticos científicos de sismos: peligros y oportunidades desde una perspectiva técnica y antropológica

RESUMEN

El apoyo de la gestión del riesgo de terremotos con una comunicación sísmica clara requiere incluir la atención de interpretaciones populares erróneas sobre la predicción de sismos. Con base en datos técnicos, así como en percepciones de la antropología y la economía, este artículo discute ideas populares y sin sustento científico sobre la predicción de terremotos, así como el estado del arte de estudios científicos con bases estadísticas y con precursores físicos. Se discuten los efectos sociales y económicos documentados de las predicciones de sismos sin sustento científico para argumentar su peligrosidad; pero también se hacen notar las oportunidades que representan su divulgación y educación en entornos formales e informales. El artículo discute a la luz de la importancia que la Oficina de la Organización de Nacionales Unidas para la Reducción del Riesgo de Desastres ha otorgado a la coordinación y comunicación dentro y entre las diversas organizaciones y agencias, así como a la reciente popularidad de la llamada predicción de terremotos en México.

Palabras clave: Benín; exponente de escalado; MFDFA; espectro de singularidad; temperatura; dinámica no lineal.

Record
Manuscript received: 11/01/2019
Accepted for publication: 05/07/2019

How to cite item
Tapia-Hernandez, E., Reddy, E. A., & Oros-Avilés, L., J. (2019). Earthquake predictions and scientific forecast: dangers and opportunities for a technical and anthropological perspective. *Earth Sciences Research Journal*, 23(4), 309-315. DOI: https://doi.org/10.15446/esrj.v23n4.77206

ISSN 1794-6190 e-ISSN 2339-3459
https://doi.org/10.15446/esrj.v23n4.77206

Introduction

On March 20, 2012 a strong earthquake of magnitude 7.4 struck southern Mexico. Over the next days, other significant earthquakes around the world were registered: an earthquake of magnitude 6.6 in New Guinea on March 21; an earthquake of magnitude 7.1 in Maule, Chile on March 25; earthquakes of magnitude 8.6 and 5.5 in Sumatra on April 11; an earthquake of magnitude 6.5 in Michoacán, Mexico on April 11; and another of magnitude 6.9 in the Gulf of California on April 12 (USGS 2015). This cluster of activity, though far from unusual, was interpreted by at least one public as empirical confirmation of earthquake predictions (e.g. Univison 2013; Latinospost 2013) which drew not on peer-reviewed scientific research but rather on methods which incorporated the position of the planets, dreams and even the so-called Mayan apocalypse, slated to end this age and begin a new one on December 21 of that year.[1]

Seismicity and related hazards have killed more people than all other natural hazards combined in the past 20 years (UNISDR and CRED, 2016) and the danger that they continue to pose requires ongoing action. The most recent United Nation Sendai Framework for Disaster Risk Reduction has drawn social and physical sciences together to indicate how crucial popular knowledge about hazards can be for effective disaster prevention. This is noting that not only can clear and coherent understanding of what can sometimes be very technical issues be important for publics, but it may also be crucial to facilitate coordination between institutions and stakeholders at all levels including community-based organizations, non-governmental organizations, and governmental organizations at local, national, and international scales (UNISDR 2015)[2]. In this context, non-expert familiarity with basic information about earthquake hazards may be essential for risk management. Scientifically unsubstantiated ideas about seismicity like those that we refer to above are not necessarily opposed to good earthquake risk reduction practices. The impetus of preparation need not be a scientifically verified threat to be potentially helpful; indeed, a marked rise in discussion of earthquake hazard and interest earthquake insurance interest was documented in the wake of a spurious prediction of a 1989 earthquake on the New Madrid fault (Shipman et al., 1993). An understanding that a scientifically viable threat is not necessary to encourage useful activity has informed a strategy by the Centers for Disease Control to encourage emergency preparedness through discussion of a zombie outbreak (CDC 2015).[3]

Although preparedness activities inspired by any threat can contribute to public safety, the spread of misinformation can be dangerous. Misinformation can frighten people and facilitate miscommunication or mistrust, unpredictable social trends, or demands for resources. Inaccurate seismic forecasts may be detrimental to public wellbeing in ways that drawing playfully on a horror-movie hazard are not. Mistaken expectations about the degree to which seismic hazard can be predicted may create confusion and has been found in some circumstances to be related to activities that might have negative impact on potentially vulnerable populations and undermine the authority of scientific experts (Stallings 1995). The formal and informal outreach and education about seismicity and earthquake risk mitigation strategies can be observed in the context of popular fascination with prediction, writing editorials in newspapers, giving talks, or simply engaging in ordinary conversation with friends, family, and colleagues. In light such activities, the state of the field of earthquake forecasting is a matter of some importance for earthquake engineers and other experts. Knowledge of a hazard does not necessarily spur effective disaster prevention activities (Landeros-Mugica et al., 2016). However, with a clear understanding of the state of research on both seismic forecasting and the dangers and opportunities provided by predictions, technically-trained experts can better consider their intervention and outreach work. Such labor, whether formal or informal, paid or unpaid, may substantially support the kind of general communication and coordination that we know can support prevention, save lives, and speed recovery.

This paper has the following goals: first, to outline current mechanisms for forecasting earthquakes, and second, to describe documented dangers and opportunities afforded by popular interest in earthquake prediction. Finally, we call for further systematic research on how the formal and informal communication about earthquakes undertaken by experts may contribute to public safety as well as on the effects of erroneous predictions for both disaster prevention works**.** Although some commentators have described “a tendency on the part of officials to see disaster planning as a product, not a process” (Wenger et al. 1980), authors are of the opinion that facilitating the ongoing discussion and the circulation of useful information regarding earthquakes is part of the necessary, but sometimes frustrating, process of effective disaster preparation.

On “prediction”

The prediction of an earthquake is defined as future seismic event may or may not occur in a region, a period of time, and magnitude with probability p ($0.0 < p < 1.0$) that the earthquake occurs in order to warn the population about the risk.

The most memorable prediction occurred in 1975 in Haicheng, China, where the changes in ground elevation, along with levels of groundwater, the behavior of animals and short quakes allowed an evacuation, just few hours before the earthquake. However, rather than the application of a methodology to provide a certain probability of occurrence, the prediction was based on coincidences and circumstantial facts. This illustrated by the fact that local experts failed to accurately predict another similar event. Indeed, thirty incorrect predictions were made just in two years (1997 to 1999). This scenario dismissed the credibility and forced the Chinese government to intend to stamp out wrong warnings and mass evacuations (Saegura 1999).

The interest of society in predictions is supported by the uncertainty of the scientific understanding of seismic activity and the threat that represents. In fact, they might have circulation in the social media and press. Some of them, that apparently account a tested methodology, are occasionally even published in scientific venues (e.g. Curiel 2010; Straser et al. 2019). In particular, the earthquake predictions of Gabriel Curiel, which suggest that gravitational forces create a “season of earthquakes” between October and December, were presented in the 2010 *Mexican Conference of Earthquake Engineering* and, subsequently, published on Curiel’s blog and referenced in countless newspaper articles (e.g. Univision 2013; Latinospost 2013), despite its lack of scientific support or even any attempt to offer convincing statistical evidence (Curiel 2010).

Despite of the fact, that it is known that the available prediction methodologies have null scientific support, forecasting approaches continue to develop. After the 2009 L’Aquila earthquake, The International Commission on Earthquake Forecasting for Civil Protection developed a document, which reports the state of the art of short-term predictions and indicate guidelines for identification of possible precursors in order to warn the population (Jordan et al. 2011).

The main recommendations are as follow:

a. It is desirable to continue to track the scientific evolution of probabilistic seismic predictions and develop the expertise to utilize these data for operational intentions.
b. It is necessary to establish instrumented laboratories for studying seismic activity and their generation process.
c. It should develop a research project focused on seismic activity as a part of a national program to develop operational prediction methods.
d. It should develop a research time-independent and time-dependent of prediction methodologies in order to improve seismic hazard maps.
e. It is necessary to develop an operational capability for the prediction of aftershocks.
f. The validating the forecasting models should be developed from the international efforts to develop to test earthquake prediction methods.

Research on precursor physical phenomena

Gas measurement

A strong earthquake (Mw= 7.1) struck the Philippines on November 15 in 1994. The epicenter was located 48 kilometers from the Taal Volcano, where a

[1] See, also, theories circulated by Brian T. Johnstone, Keith Hunter, and those documented in Austin (2016)

[2] See particularly priority one, “Understanding disaster risk.”

[3] Jason J. Morrissette (2014) contextualizes the symbolic power of the figure of the zombie in critical security studies, while Julia Daisy Fraustino and Liang Ma (2015) critique the effectiveness of the social media campaign.

research of gas emission had been developed since June 1993. The recollected data reported, 22 days before the seismic activity, an unexpected increase in the emanation of a gas called Radon.

Radon is a colorless, odorless and tasteless gas. It is the most studied terrestrial gas for the purpose of earthquake prediction.[4] Earthquake forecast research involves measuring α rays associated with the radioactive disintegration (Igarashi and Wakita 1995). Then, the observation reported by Richon et al. (2003) and other similar researches indicated the possible identification that radon gas could be associated with the increased stress in the tectonic plates which may cause an earthquake.

Some other researchers have reported geochemical changes before an earthquake. For instance, two weeks before the magnitude 6.8 Nagano Prefecture earthquake, Hirotaka and others noted variations of soil-gas radon recorded 65 km from where these measurements were taken in Japan in 1988 (Richon et al. 2003). Igarashi et al. (1995) noted similar radon anomalies as the one reported by Richon et al. (2003). Abnormal emanations of soil gases (radon, helium and dihydrogen) were reported at several locations following the magnitude 8.0 Sichuan earthquake of May 2008 (Zhou et al., 2010; Zheng et al., 2012).

In addition, an anomalous radon ^{222}Rn decrease was detected (Fig. 1) as a different precursor starting about 2 days before a magnitude 6.0 earthquake in Japan in 1991. The anomalies were reported about 200 km from the epicenter by Wakita and others (Igarashi and Wakita 1995).

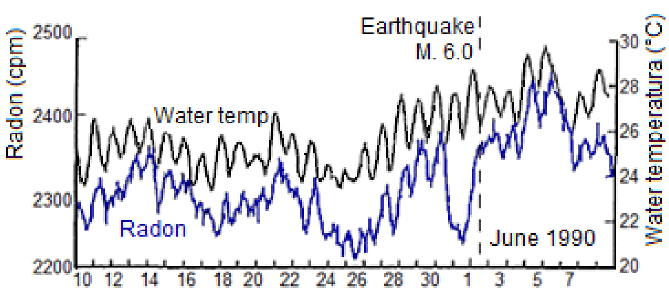

Figure 1. Anomalous radon ^{222}Rn decrease recorded before an earthquake (adapted from Igarashi and Wakita 1995)

With this scenario, the hypothesis was that the near-failure compression with imminent movement produces emissions of gas radon ^{222}Rn, much as if it is being squeezed from the tectonic plates. Thus, an increment of emanation might anticipate a seismic activity**.** In controlled conditions in laboratory tests, the increment of the stress in a rock sample under uniaxial compression had been related with before an increment of the emanations of gas radon ^{222}Rn (Igarashi and Wakita 1995).

For this reason, observations of the emanations have been investigated at various places, and different methodologies have developed to relate the radon ^{222}Rn emanation and seismic activity (e.g. Segovia et al*.,* 1999; Omori et al*.,* 2007; Richon et al*.,* 2010). However, the results are not definitive and cannot be generalized, since the seismic activity continues happening without gas emanation in all cases (Richon et al*.,* 2010). And also, earthquakes have also occurred without abnormal emanation of gas radon ^{222}Rn (Peña 2003). For instance, an anomalous radon decrease was reported after the seismic activity, not before the earthquake in measurements from January and May 1987 in Fukushima Prefecture at the northeast of Japan (Fig. 2).

The emanation of other gases has been also studied. Abnormal measurements of helium were noted in Nagano, Japan from one to three months before the September 14 earthquake (Mw 6.8). The emanations were reported in mineral springs and gas fumaroles between 9.0 to 95.0 kilometers from the epicenter (Nagamine and Sugisaki 1991).

Hydrogen is produced in the cortex through a complex process. For this reason, Hydrogen is not studied as an indicator of earthquakes as other gasses. Kato and others demonstrated in laboratory tests that samples of granite under compression load might be related to the emanation of Hydrogen. Furthermore,

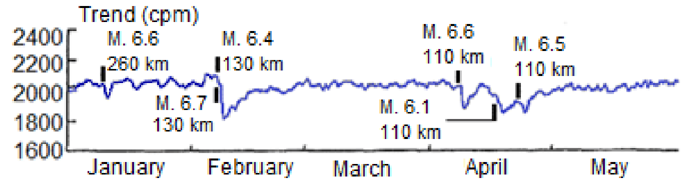

Figure 2. Observed data on radon concentration (adapted from Igarashi and Wakita 1995).

Stake and others noted an abnormal emanation of Hydrogen in bubbles of mineral springs in five locations just one month before the May 26, 1983 earthquake in Atotsugawa and Ushikubi, Japan (Mw= 7.7) and before the September 14, 1984 earthquake in Nagano (Mw= 6.8) (Igarishi and Wakita, 1995).

In contrast to the above, more than 150 studies have reported that measurements of gases might not be a proper reference of chemical concentration underground at considerable depths. This is due thermo-mineral waters contacts a considerable volume of rocks at various depths, so the records are not necessarily more representative of the environment at the tectonic plates. Because of this, it is desirable to study the relationship between the gas emanations and the environmental disturbances such as atmospheric pressure, tide, temperature, rainfall, barometric pressure, soil moisture, wind temperature, volcanic disturbances, etc. (Segovia et al*.* 1999)**.**

Nevertheless, the study of gases emanations has been a typical effort in less-than-scientific earthquake predictions and, indeed, they have appeared too often in public discussions of the seismic activity. For example, the prediction made by Giampaolo Giuliani before the 2009 L'Aquila earthquake was established form gases measurements. After the event, Giuliani became recognized in social and popular media for the apparent efficacy of the measurements, despite of he had been asked to desist from frightening the society after he had made some incorrect predictions (Hall 2011; Cartlidge 2012).

Geophysical observations

The seismic activity has been associated also to electromagnetic phenomena. For instance, light flashes were related with earthquakes in Derr in 1973 and Komogawa and others in 2005. Similarly, electromagnetism effects were reported by Gokhberg and others in 1982 and Nagao and others in 2002. Atmospheric electric fields were reported by Kondo in 1968 and Vershinin and others in 1999. Ionospheric perturbation was discussed by Nagaov and Hayakawa in 1998 and Liu and others in 2000 (Omori et al. 2007).

The chemistry and isotope components of water were studied in 9 geothermal fields located around the Anatolian Fault in Turkey from 2002 to 2004 in order to investigate their relationship with earthquakes. The study report changes in chemical and isotopic balance, which it seemed to be related with seismic activity of moderate magnitude (Süer et al., 2008).

Additionally, the relationship between the December 2004 earthquake in Sumatra and the F-region ionospheric parameters probed remotely by a digital ionsonde over New Delhi have been also studied. According to the results, perturbations in FoF2 and hmF2 were noted several hours before the seismic activity (Dutta et al. 2007).

A correlation was established between an anomalous cloud in geostationary satellite sensor above the active Iran fault by Guo and Wang (2008). Thick clouds had spread along the tectonic plate with high temperatures, 69 days after the seismic activity. Similar clouds were also noted, 64 days after an earthquake of magnitude 6.0 on December 2005.

With this scenario, despite the large number of possible precursors, no definitive results have been achieved. Namely, in a probability space ($\mathcal{F}$ P), where $\mathcal{F}$ is a set of events, P is a set of probabilities, M is the precursor and N is an earthquake occurrence ($M, N \in \mathcal{F}$). If the probability of event occurrence exists P(M) > 0 and the probability that earthquakes in that geographic region exists P(N) > 0; then, the conditional probability of N in relation of M is defined as the equation 1.

$$P(M|N) = \frac{P(M \cap N)}{P(N)} \quad (1)$$

[4] There are three radon isotopes: ^{222}Rn ($T_{1/2}$= 3.825 days), ^{220}Rn ($T_{1/2}$= 54.5 s) and ^{219}Rn ($T_{1/2}$= 3.92 s). Generally, radon refers to ^{222}Rn since it has the longest half-life and, therefore, is of most geochemical interest.

P($M|N$) is interpreted whereas if N is satisfied, the conditional portion of M must be met. In other words, if the identified precursor occurs, the conditional probability of an earthquake also exists. The disadvantage of the methods discussed above is that the space where the precursor event M exists in relation to natural phenomena unrelated to seismic activity is extremely high**.** Similarly, there is a high probability that an earthquake will occur without a precursor N. Precursor events have been occurring without an earthquake and seismic activity has been reported without precursor events.

In general, the studies on physical precursors have demonstrated the need for simultaneous measurement of external parameters and the creation of networked monitoring stations. Nowadays, the innate randomness and frequency of earthquakes are used to sustain predictions that might produce unwarranted confidence. For the real conditions, there is still much to do to establish relevant data. Also, it is necessary to study the precursors in simulations in the laboratory as a function of the variety of cases and conditions.

Precursors based in statistical patterns

Statistical correlations from catalogs of the seismic activity and other techniques developed from probabilistic models are also under investigation. These methods are based on i) diminutions of earthquakes in a region (seismic gap), ii) the tendency of the epicenters motion, iii) increments of earthquakes in the periphery of a region (donut pattern) or iv) the increase of seismic motions at low magnitudes in a particular region (swarms).

Statistical methods are based on data collected with stations, records of the historical seismic activity and from collaborations between historical anthropologists and geophysicists (e.g. García and Suárez, 1996 and Zuñiga et al. 1997).

It is supposed, according to the elastic-rebound theory, that the tectonic plates develop stress progressively and during an earthquake, the energy is released suddenly. And after the seismic activity, it starts another energy accumulation period that will produce a new earthquake and so on. Then, a seismic gap is an active fault that has not slipped in a long time when compared with other regions along the same tectonic plate.

For instance, at the state of Guerrero in southern Mexico, an earthquake has been anticipated for many years, based on historical records. Supposedly, the accumulated energy is enough to produce a strong earthquake. The information about the disastrous magnitude was spread to the society after the 8.1 earthquake of September 19, 1985 by geophysicists and the potential danger of this gap (UGM, 1986). Based on this, an earthquake early warning system was expanded along the region by policymakers in Mexico (Espinosa-Aranda et al. 2009). Locally, the seismic activity has been studied using models of the physical processes and Bayesian statistics in order to make adequate use of the available information since then (e.g. Singh and Ordaz 1994). However, the predicted strong earthquake has not struck the country. It is thought two scenarios: i) the energy continues accumulating and will lead to rupture someday, producing an even major earthquake or ii) the release movement has already happened by way of "silent" earthquakes.

The release of energy through the displacement of the plates for several days is called silent slip earthquakes. Nowadays, they can be distinguished by GPS monitoring. For instance, Figure 3 shows the location of seven sites in southwestern British Columbia, Canada, where red arrows show the detected displacements by continuous GPS**,** while black arrows show the common GPS motions. Namely, the studied sites reversed their direction of motion. The unusual displacements were estimated about 2 centimeters in the range from 6 to 15 days; so, the slip over a 50-kilometer by 300-kilometer area was equivalent to an event of a magnitude 6.7 (Dragert et al. 2001).

The probability that an earthquake might occur based on the identification of historical records is uncertain. For example, in Parkfield, United States was predicted an earthquake based on previous events recorded in 1857, 1881, 1901, 1922, 1934 and 1966 (Bakun et al. 1987; Mileti and Fitzpatrick 1992) as depicted in Figure 4. The identification of a seismic gap and a return period of 21.9 years were estimated with a probability of occurrence at 95%. Nevertheless, the seismic activity did not occur until September 2004, deviating from the trend.

Thus, the search for earthquake precursors useful in a short-term has had no success yet in any sense, but their possible effects might be powerful.

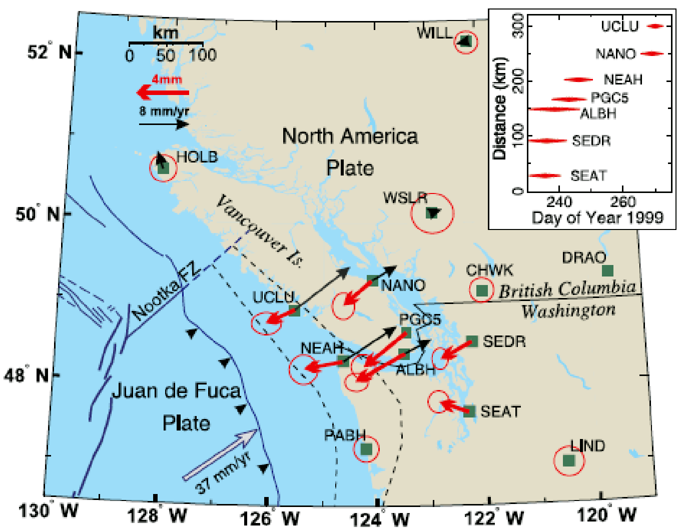

Figure 3. Description of GPS sites in Canada in the summer of 1999 (from Dragert et al., 2001)

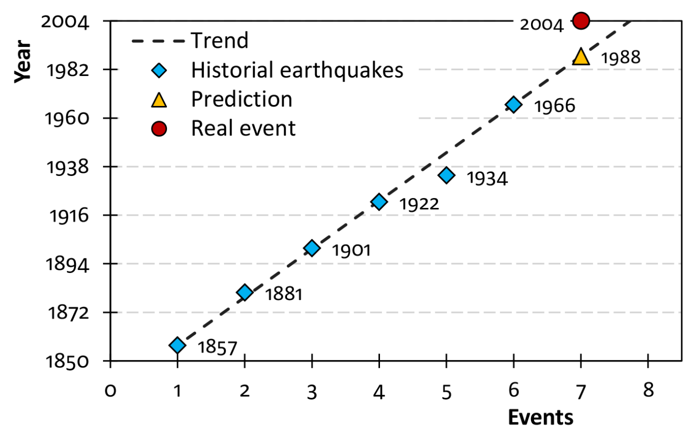

Figure 4. Statistical projection of expected earthquake in Parkfield, United States

Prevention activities and earthquake prediction

Disaster is a complex of social and physical effect (O'Keefe et al. 1976; García and Rojas 1994; Oliver-Smith 1996). Disaster is not the sure outcome of a large earthquake, but instead the product of impact on people. This means that we can mitigate disaster by taking steps to prepare for earthquakes. Understanding that earthquakes are likely to happen in certain areas and at certain magnitudes can support such preparation; however, when preparation is anchored to a predicted event at a given time and place, there is significant concern that this, too, can be dangerous, though in oblique ways that can be difficult to prove in the complex welter of social action.

The recent UN Sendai Framework on Disaster Risk Reduction (UNISDR 2015) addresses social and structural issues as a part of vulnerability, highlighting the ways that vulnerable people are disproportionately affected by disaster. The Sendai Framework defines vulnerability, in reference of Hyogo Framework, as "the conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards" (UNISDR 2005). This means that factors such as knowledge, income, type of work, social support network and qualities of the built environment itself such as where homes or other important structures are sited, access to services like electricity or sewage or roads and local resource depletion or contamination can be considered to contribute to vulnerability of a community to disaster.

Strategies suggested by the Sendai framework (UNISDR 2015) are wide ranging, including understanding disaster risk; strengthening disaster risk governance to manage disaster risk, investing in disaster risk reduction for resilience, and enhancing disaster preparedness for effective response, recovery, rehabilitation and reconstruction. Some of this, falls under the purview of state actors, but especially as many bureaucracies find hazards challenging in the extreme (Dynes et al. 1990; Perrow 2008). Indeed, fostering prevention activities broadly and facilitating clear communication and integration of efforts by state and non-state actors at local, national, and international levels has been identified by the United Nations Office for Disaster Risk Reduction, as a strategy to diminish the risks that potentially- disastrous hazards pose well in advance of any danger.

There is nothing controversial here, nor is there much debate regarding the understanding that a general awareness of a hazard is highly desirable for earthquake risk reduction (FEMA-474, 2005), especially if the members of the population are represented by the possible actions that can be taken (Farley et al. 1993; Mileti and Fitzpatrick 1993), and can be an excellent foundation upon which to build further interventions (Gratton et al. 1987; Mileti and Fitzpatrick 1992). This kind of awareness is certainly most helpful when it resonates with informed understandings of how earthquakes happen and are likely to affect populations and can be used in multiple and even creative ways (as Barrios 2014 argues). However, it can also be troublesome. Not only can emergency planning itself face significant apathy and resistance, articulating the management of action often with the management of human emotion or affect[5], but also the kinds of experience with hazards and knowledge about them are also sometimes related to avoidance or unwarrantedly optimistic assessment of safety (Landeros-Mugica et al. 2016). Despite of experts hope that they might encourage planning and preparation.

Prevention does not necessarily depend on scientifically informed understandings of hazard, though multi-modal and detailed communication around a threat has been found to be a key strategy for emergency hazard communication (Mileti and Sorensen 1990; Sorensen 2000). This is a fine line to parse, but an essential one. Substantial anthropological evidence indicates that particularly well-established and pervasive belief systems, whether scientifically informed or non-informed, are likely to be efficacious in the face of hazards common in the contexts in which they emerged. The adaptability and creativity based on traditions represented significant support in the past (Torry 1978; Oliver-Smith 1994) and might offer a powerful lesson for risk mitigation (Turton 1977; Oliver-Smith 1986).

Indeed, the potential utility of unscientific belief systems is supported in law; for example, the experience of L'Aquila residents. In the wake of a deadly 2009 quake there, a court case was brought against the experts. They, reacting against the spurious predictions of Giampaolo Giuliani (noted above), assured that it was unlikely that an earthquake was forthcoming. These assurances dissuaded the population from following local custom to sleep outside in the advent earthquake swarms, and for their part in 32 L'Aquila deaths, the experts were convicted of manslaughter, since overturned (Alexander 2014). Policy frameworks including Sendai (UNISDR 2015) explicitly highlight traditional informed practices potentially useful or even models for the development of effective practices.

If not necessarily dangerous in and of themselves, popular expectations about the predictability of earthquakes may become so if they interfere with potentially lifesaving actions, causing them to be put off or misapplied. Although research in the social sciences demonstrates that panic is often less extreme than expected (Mileti and Sorensen 1990, Tierney 2003), anxiety involved in earthquake predictions may still have effects on institutional resources and economic activity in significant ways (Haas and Mileti 1976; Weisbecker et al. 1977).

Institutional & economic impacts of earthquake predictions

There are clear mechanisms by which earthquake predictions might be understood to influence expectations and affect economic activity and formal political relations. They may do so in both positive and negative ways. On the one hand, earthquake damage, often calculated as damage to a year's expectation of economic gain, can happen here even in the absence of an actual earthquake (though not in a way that insurance can be drawn upon to defray) as people evacuate, fail to visit, and change their investment plans. These kinds of impacts in advance of a hazard that may not occur can be referred to as a matter of "psychological foreshocks" (Olson et al. 1989). On the other, such predictions may happen in concert with increased economic activity, as people stock up on emergency supplies (as Shipman et al. suggests they did in advance of a prediction regarding the New Madrid fault in 1993). They might take action, further, upon their expectations regarding possible losses, expected profits, and market depreciations. Indeed, earthquake predictions based on well-established systems and pervasive beliefs, could modify short term spending and institutional demands with potentially wider repercussions by means of longer-term plans and market activity.

In economic theory, decisions are often discussed with an inter-temporal approach: an investment decision is determined by the relationship between understood conditions of the past, of the present, and those likely in the future. This can be considered as a matter of incentives, and the scale of such incentives relate extant possibilities to potential increases in production (Mankiw 2007). Business owners and investors' forecasts alike, and their confidence about forecasts, can be critical to investment decisions. Their decisions do not only pertain to their own endeavors but can come to involve investors and related industries through market mechanisms, which can spread impact of investment decisions widely.

The assurance with which some earthquake predictions are deployed can be very persuasive, and may not only be expressed around single events, but also with respect to longer time frames or returning seasons ("earthquake season" for example). Scientific forecasting can certainly influence economic decision making. However, predictions with strong assertions of regarding when an earthquake will happen, how large it will be, and where it will be felt, may appear more concrete than the general forecasts that current state-of-the-art forecasting can offer. These, then, can motivate economic action in the same way as they motivate preparatory action: in ways that are potentially beneficial and quite troubling, but may in the end be less extreme than experts worry (Olson and Olson 2001).

The confidence on predictions can affect economic activity of consumers, business planning, and potentially markets; they can create challenges for public facing institutions of many kinds. Olson et al. (1989) document the Brady-Spense prediction of an earthquake in 1981 and some of the scientific and institutional conflicts which surrounded it and emerged out of it. As news of a potentially credible earthquake prediction spread and became highly politicized in the US and in Peru (the territory likely to experience its impacts) people with different goals, interests, and expertise became involved in responding to the threat. Many organizations were unprepared for the demands that the prediction could inspire. While Olsen et al. documented how the event catalyzed new Peruvian assessments of risk and disaster response capabilities, the international assistance possibilities available, and how it raised public awareness of earthquake threat, they also demonstrate the kinds of institutional pressures that were created as business as usual in state institutions. For example, Peruvian Civil Defense was overwhelmed with requests for trainings, and could only respond to a fraction of them. Predictions can create unexpected conditions, interfering with planning; and while this may open the door for new opportunities, it may also create serious trouble for mid- and long- range planning.

Conclusions

In newspapers, television, and social media, predictions about earthquakes circulate. Sometimes, these predictions refer to religious or mystical explanations. They may seem scientific to people unfamiliar with seismic science, referencing studies or data that readers may find difficult to parse. This paper draws on engineering, anthropological and economic scholarship to provide an overview of the current state of the field in earthquake forecasting and discuss the social and institutional implications of earthquake predictions. It pretends to give earthquake engineers the tools they need to understand current research and engage with non-expert members of the public and facilitate the kinds of coordination between institutions and stakeholders at all levels including community-based organizations, non-governmental organizations, and governmental organizations at local, national, and international scales called for by the United Nations Office for Disaster Risk Reduction.

[5] On the topic of the historical and politically-situated promises and dangers of the management of fear in particular see Daston (2008) and Massumi (2005).

Engineers are highly trained members of professional and non-professional communities who may engage with their peers on the topic of predictions formally and informally. Many correct misapprehensions and answering questions, even when they are not employed to do so, providing bases by which untrained members of their communities can better understand the sometimes-confusing information they may receive about scientific research on statistically-based earthquake forecasts and seismic precursors, as well as the predictions based on ideas about earthquake seasons or ancient mystical knowledge which sometimes circulate alongside other kinds of earthquake information in the popular press. This paper provides an overview of cutting-edge scientific research into physical precursors and statistical methods of earthquake forecasting and a discussion of the potential impacts of public education regarding seismic threat can have.

Unlike other natural phenomena, earthquakes are not, generally speaking, predictable. Statistical and precursor research is nonetheless providing key insights into seismic effects in various local environments. In correcting misapprehensions, trained experts may misestimate the negative effects that predictions can have. Frustrating and troubling as they might be, they also provide opportunities that, if seized, may be turned to useful effect for 1) public education and outreach regarding earthquake safety and 2) collaboration in and between government and non-governmental institutions at local, regional, and national scales.

As discussed in this paper, substantial anthropological evidence indicates that technical knowledge about seismicity may not be significantly correlated to effective public practices for earthquake risk management. Nonetheless, widespread confusion and poor communication around predictions can cause interruptions to normal activity that may be both deleterious and offer opportunities for outreach about effective preparation activities. Further, as responses to prediction and public concerns may necessitate the involvement of professionals without significant technical knowledge about seismicity, the understanding that a general public has of earthquake science and that of experts in the field are not the only ones of import. Professionals with various responsibilities may become involved in the case of an earthquake prediction. Understanding not only the geoscientific context of predictive possibility but also the social science on the risks around it may facilitate the kinds of reasonable action necessary to make the most of predictions.

As erroneous earthquake predictions continue to seize popular attention without scientific support, it would be very useful indeed to critically evaluate their effects --both positive and negative-- on community disaster preparation. Additionally, it was noticed a great potential utility for systematic research on the effects of formal and informal expert communication about earthquakes, the state of scientific knowledge regarding forecasting, and the bases of earthquake prediction efforts. We suspect that the outreach research that we and our colleagues do can facilitate the production of shared understanding about seismic conditions and hazards and contributes to coordination that the UNISDR has recognized as crucial for supporting prevention, saving lives, and speeding recovery. Despite of the complex social effects of predictions that have been discussed in this paper; authors maintain that if seismicity and related hazards continue to pose the same kinds of threats to human life, then any excuse for outreach and building effective networks of collaboration must be seized.

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