FREQUENCY AND SEVERITY OF EARTHQUAKES: EARTHQUAKE AND VOLCANIC EVENT PREDICTION

P. F. Biagi
University of Bari, Italy

Keyword: earthquakes , frequency, Severity, volcanic eruptions, precursors, prediction, reliability

Contents

Summary

Earthquakes are shown to be both a frequent and a dangerous phenomenon. Volcanoes can also be very dangerous when the eruptions are explosive. Methods of predicting volcanic eruptions and earthquakes exist, and a method used to predict earthquakes has been presented as an illustration. All these techniques, however, have their limitations, and there have been very few examples of true predictions that have enabled cities to be evacuated.

1. Introduction

The lithosphere is broken into a series of slabs known as lithospheric or tectonic plates. These plates are rigid, but they float on the hotter, softer layer in Earth's interior. There are 16 major plates and several minor plates. Plate boundaries are areas where Earth's shifting plates collide or split apart (see *Tectonic Processes*). Plate margins that are coming together are called convergent margins, while those that are splitting apart are called divergent. Along convergent margins, two plates meet and one descends beneath the other, a process called subduction. At divergent margins, plates are coming apart and hot rock forces its way to the surface. At a third type of boundary, transform-fault margins, plates slide against each other, going in opposite directions. A well-known example of a transform is the San Andreas Fault in California, which separates the Pacific and North American plates.

Ninety percent or more of all earthquakes occur along the plate boundaries. Earthquakes at transform-fault margins and at divergent margins tend to be shallow (less than 25 km

UNESCO – EOLSS SAMPLE CHAPTERS

deep) and have magnitude smaller than 8.0. The compressional boundaries at convergent margins create a wide range of earthquakes from very the near surface to several hundred kilometers depth, since the coldness of the subducting plate permits brittle failure down to as much as 700 km. These boundaries host Earth's largest earthquakes, with some events having M up to 9. It is also possible for earthquakes to occur a long way from plate margins.

2. The Earthquake Threat

Earthquakes are among the most devastating and terrifying of all natural hazards. The destruction of property and life are determined by many interrelated factors, including:

a) the amount of seismic energy released and the duration of shaking (both parameters depend on the magnitude of the earthquake);
b) the depth of focus—shallower earthquakes generate more destructive shock waves at Earth's surface;
c) the distance from the epicenter—the potential for damage tends to be greatest near the epicenter and decreases further away from it;
d) the geological setting—the foundation materials exhibit a wide range of responses to seismic vibrations (for example, earthquake vibrations last longer and develop greater amplitudes in soft, unconsolidated material than in areas underlain by hard bedrock);
e) the densities of the local population and buildings—in general, the risk increases with an increase in population and building density;
f) the types of buildings—wooden frame structures tend to respond to earthquakes better than more rigid brick or masonry buildings;
g) time of day—experience shows that there are more casualties if an earthquake occurs at night, because most people are at home sleeping and are thus not in a good situation to respond properly.

2.1 Occurrences and Impact of Earthquakes

The frequency of occurrence of earthquakes in the world depends on their magnitude. Table 1 reports the frequency of earthquakes based on observations since 1900.

Type	Magnitude	Yearly Average
Great	8.0 and higher	1
Major	7.0–7.9	18
Strong	6.0–6.9	120
Moderate	5.0–5.9	800
Light	4.0–4.9	6 200
Minor	3.0–3.9	49 000
Very Minor	Less than 3.0	About 9 000 per day

Table 1. Frequency of occurrence of earthquakes in the world

UNESCO – EOLSS SAMPLE CHAPTERS

During 1999, 17 earthquakes with M between 7.0 and 7.9 (major types) occurred in agreement with the yearly average given in Table 1. The event in Turkey (M = 7.7) of 17 August and the Taiwan quake (M = 7.2) of 20 September were particularly devastating in terms of sudden loss of life and property. Some data related to the Turkish earthquake are listed here:

- *deaths*: 15 135 counted plus about as many *missing*;
- *hospitalized injuries*: about 24 000;
- *collapsed houses*: 50 000;
- *houses damaged beyond repair*: about 120 000;
- *collapsed buildings*: about 2000;
- *heavily damaged buildings*: about 4000;
- *number of people that need to be housed*: 600 000;
- *monetary losses*: about US$16 billion.

Some data related to the Taiwan earthquake are listed here:

- the official *death toll* stands at 2 105, with 8 713 people injured, 141 missing or trapped, and 100 stranded in remote areas;
- the earthquake *destroyed* around 13 000 high-rise apartment blocks in central Taiwan, and left more than 100 000 people *homeless*;
- the *monetary damage* was of about US$4 billion.

Often, the damage caused by earthquakes is connected to the aftershock activity as well as to the main event. In September 1997 a strong earthquake (M = 5.9) occurred in central Italy near to the historic and well-known city of Assisi. A strong aftershock activity took place in the zone, after this earthquake. In six months, 18 000 earthquakes occurred, and seven shocks had magnitude greater than 5.0. Many villages of the zone bore the main shock fairly well, but they collapsed in consequence of the aftershocks. For example, the small town of Nocera Umbra was damaged by the main shock, and it was destroyed by the aftershock activity.

As a summary, earthquakes have killed 3.5 million people or more in the world during the period from 1900 to 1999.

3. Earthquake Prediction

Scientists are currently looking at ways of predicting earthquakes. The possibility of predictions is mainly based on the existence of "premonitory signals." The premonitory signals can be divided into statistical precursors and empirical precursors.

3.1 Statistical Precursors

Statistical analysis is one method of predicting earthquakes. A statistical analysis can be made by looking at the history of earthquakes in a given region, and seeing if there is a recurrent, or cyclical, pattern of earthquakes. In order to illustrate the statistical analysis approach, we will examine the case of the Friuli earthquake (M = 6.9), which occurred in Italy on May 6, 1976. Using data from the seismic catalogue of Italian earthquakes,

UNESCO – EOLSS SAMPLE CHAPTERS

nineteen earthquakes in the Friuli region occurred before 1976. These were strong enough to damage houses. Five of them were powerful enough (“strong” earthquakes) to cause serious devastation. The following list of dates is considered to be reliable: 1116, 1223, 1278 (strong), 1279, 1348 (strong), 1364, 1389, 1472 (strong), 1511, 1690 (strong), 1692, 1700, 1788 (strong), 1790, 1841, 1855, 1876, 1881, and 1928. A statistical analysis of these earthquakes reveals an average interval between them of 43.26 years. The last previous earthquake occurred 48 years before the 1976 earthquake. From statistical calculations, which assume a random recurrence of earthquakes, it is possible to calculate that by 1976, there was a 67.7 % probability of an earthquake that could damage buildings. If only the five strong earthquakes are considered, the average interval is 127.5 years. However, by 1976, 188 years had elapsed since the last strong earthquake, the one in 1788. Thus, there was a 77 % probability of a strong earthquake.

-
-
-

TO ACCESS ALL THE **15 PAGES** OF THIS CHAPTER,
Visit: http://www.eolss.net/Eolss-sampleAllChapter.aspx

Bibliography

Bella F., Biagi P. F., Caputo M., Cozzi E., Della Monica G., Ermini A., Plastino W., and Sgrigna V. (1998). Field strength variations of LF radio waves prior to earthquakes in central Italy. *Physics of the Earth and Planetary Interiors.* **105**, 279–286. [Application of radio wave methods in earthquake predictions.]

Biagi P. F., Ermini A., Kingsley S. P., Khatkevich Y. M., and Gordeev E. I. (2000). Groundwater Ion Content Precursors of Strong Earthquakes in Kamchatka (Russia). *Pure and Applied Geophysics.* **157**, 9.[Groundwater precursors of strong earthquakes.]

Decker R. and Decker B. (1989). *Volcanoes*, 285 pp. New York: W. H. Freeman and Company. [Introduction to volcanoes.]

Hayakawa M. and Fujinawa M., eds. (1994). *Electromagnetic Phenomena Related to Earthquake Prediction*, 507 pp. Tokyo: TERRAPUB. [Electromagnetic phenomena related to and applicable to earthquake predictions.]

King C. Y. (1986). Gas geochemistry applied to earthquake prediction: An overview. *Journal of Geophysical Research*, **91**, 12269–12281. [Earthquake predictions via gas geochemistry.]

Rikitake T., ed. (1967). *Earthquake prediction: developments in Solid Earth Geophysics*, 357 pp. Amsterdam: Elsevier. [Review of earthquake prediction methods.]

Simpson D. W. and Richards P. G., eds. (1981). *Earthquake Prediction: An international Review*, 680 pp. American Geophysical Union. [Review of earthquake predictions.]

Stuart W. D. and Aki K., eds. (1987). Intermediate-term earthquake prediction. *Pure and Applied Geophysics.* **126**(2–3, 6), 541. [Overview of very short-term earthquake predictions.]

Wyss M. and Booth D. C. (1997). The IASPEI procedure for the evaluation of earthquake precursors, *Geophysical Journal International*. **131**, 423–424. [International procedure of how to evaluate earthquake precursors.]

Wyss M. and Dmowska R., eds. (1997). Earthquake Prediction—State of the Art. *Pure and Applied Geophysics.* Topical Volume **149**.270pp. [Review of earthquake prediction art.]

UNESCO – EOLSS SAMPLE CHAPTERS

Biographical Sketch

Pier Francesco Biagi, was born in Forlì, Italy, on February 10, 1944. He obtained his degree in physics in 1968 at the University of Rome "La Sapienza". From 1976 to 1994 he was Associated Professor of Applied Geophysics at the University of Rome "La Sapienza." Since November 1995 he has been Full Professor of Physics at the University of Bari. For about twenty-five years his principal interest has been the study of precursory phenomena of earthquakes. He was the convener of sessions on earthquake precursors at the European Geophysical Society Assemblies and at the International Conferences on Rare Gas Geochemistry. He has been the Italian scientific adviser responsible for several CEE projects regarding earthquake and premonitory signals. He is a member of the American Geophysical Union, of the European Geophysical Society, of Natural Hazard, and of the Italian Society of Physics. He initiated several scientific international cooperations and two of them are particularly active, namely, a cooperation with researchers of the Geochemical Service of Kamchatka and one with scientists of the University of Electro-Communications in Tokyo. His scientific production consists of about 120 papers.

UNESCO – EOLSS
SAMPLE CHAPTERS