Geo Factsheet

September 2002 www.curriculumpress.co.uk Number 133

EARTHQUAKES:

Why do some places suffer more than others?

Introduction

Earthquakes are probably the most frequent of all natural hazard events, yet their impact on people, property and communities varies enormously from one place to another. In this Factsheet we will examine the reasons why the impact varies so much and we will try to answer the question, "Why do some places suffer more than others?" Suffering can be measured in terms of deaths and injuries to people, and amount of damage to property and installations. The title of this Factsheet reflects a typical synoptic essay question at A2 level and the structure that follows is intended to act as a guide to ensure that such a question is answered appropriately.

An earthquake event only becomes a 'hazard' when it impacts on people or on people's activities. Many earthquakes happen in remote areas or underwater or are too small to cause damage or concern. However, every year a good number of earthquakes cause loss of life, sometimes into the thousands. It is possible to identify a number of factors that cause some places to suffer more than others. Some are large scale and are to do with global location, such as the tectonic setting, and others are at a much more local scale and relate to building design and levels of preparedness.

Factors:

1. *Tectonics and the global distribution of earthquakes*
2. *Earthquake magnitude and depth*
3. *Population density*
4. *Building and structural vulnerability*
5. *Extent of earthquake preparedness*
6. *Levels of development*
7. *Nature of bedrock*

1. Tectonics and the global distribution of earthquakes

The distribution of earthquakes is commonly linked to the margins of the global plates. The statement that "earthquakes occur at plate margins" is broadly true. However, it is a gross simplification for it assumes that earthquakes are more common and more devastating at some margins than at others.

Fig. 1 shows the global distribution of earthquakes and the major tectonic plates and their margins. It is possible to identify the following features from the map:

- Most earthquakes do coincide with the major plate margins
- A number of earthquakes occur away from plate margins – these are often referred to as 'mid-plate earthquakes'
- Certain margins have a far greater 'density' of earthquakes than others. For example, there appear to be far more earthquakes along the west coast of South America and in the Japan/Philippine region than along the Pacific Rise or the Mid-Atlantic Ridge.
- Earthquakes form a narrower spread at some plate margins than at others. Generally speaking, the earthquakes at destructive plate margins have a greater spread and therefore affect more places than those at constructive plate margins.

Fig. 1 Location of major plate margins and earthquakes (recorded 1961 - 67)

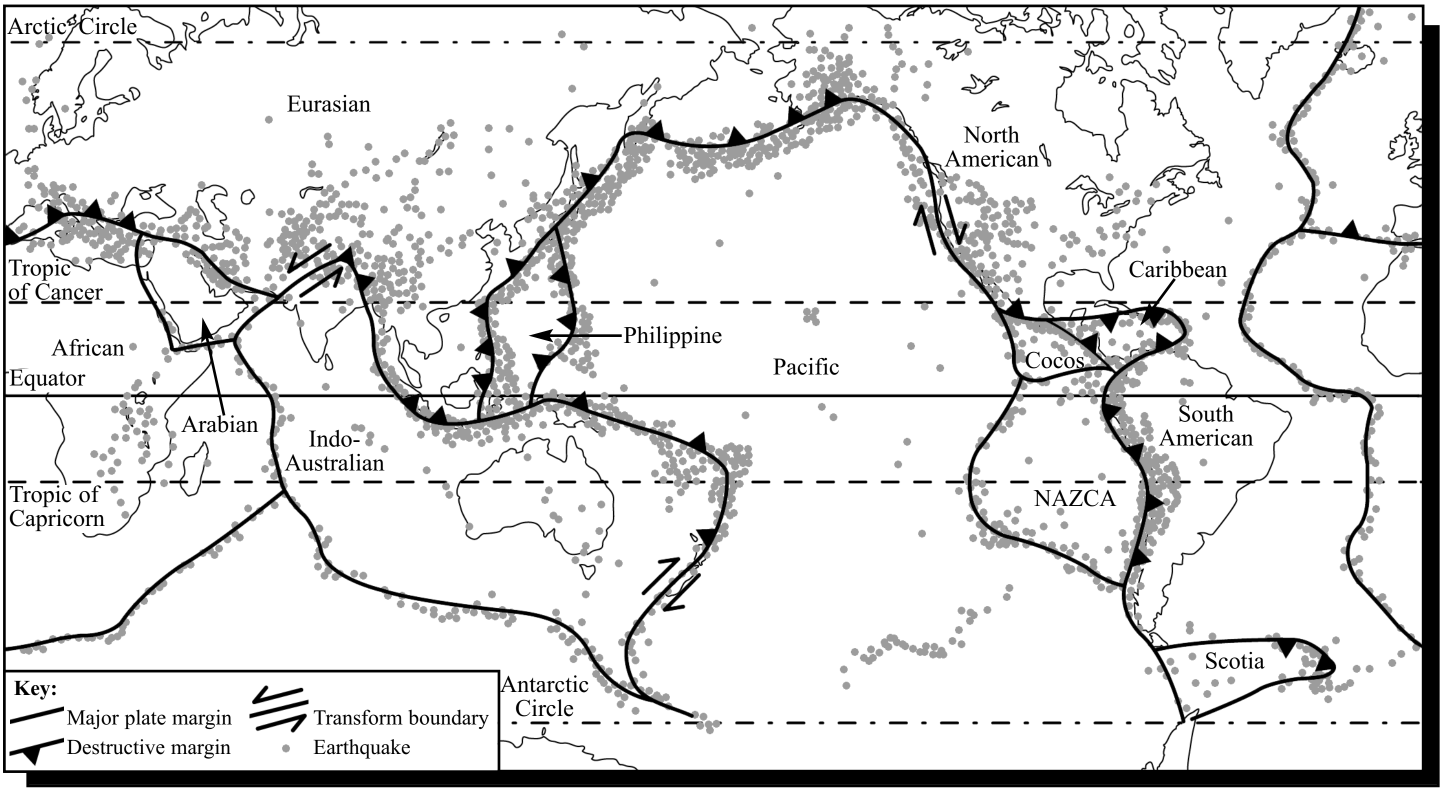


Table 1 The top twenty deadliest earthquakes from 1900.

Location	Date	Latitude	Longitude	Deaths	Magnitude	Plate margin	Comments
Tangshan. China	27/07/76	39.6N	118.0E	255,000	8.0	Destructive	
Gansu, China	16/12/20	35.8N	105.7E	200,000	8.6	Destructive	Landslides
Xining, China	22/05/27	36.8N	102.8E	200,000	8.3	Destructive	
Kwanto, Japan	01/09/23	35.0N	139.5E	143,000	8.3	Destructive	Great Tokyo fire
Ashgabat, Turkmenistan	05/10/48	38.0N	58.3E	110,000	7.3	Destructive	
Messina, Italy	28/12/08	38.0N	15.5E	70 - 100,000	7.5	Destructive	Earthquake and tsunami
Gansu, China	25/12/32	39.7N	97.0E	70,000	7.6	Destructive	
Peru	31/05/70	9.2S	78.8W	66,000	7.8	Destructive	Rock slides, floods
Quetta, Pakistan	30/05/35	29.6N	66.5E	30 - 60,000	7.5	Transform	
Western Iran	20/06/90	37.0N	49.4E	40 - 50,000	7.7	Transform	Landslides
Erzincan, Turkey	26/12/39	39.6N	38.0E	30,000	8.0	Transform	
Chillan, Chile	25/01/39	36.2N	72.2W	28,000	8.3	Destructive	
Turkey/USSR border	07/12/88	41.0N	44.2E	25,000	7.0	Transform	
Guatemala	04/02/76	15.3N	89.1W	23,000	7.7	Destructive	
Santiago, Chile	17/08/06	33.0N	72.0W	20,000	8.6	Destructive	
China	10/05/74	28.2N	104.0E	20,000	6.8	Destructive	
Iran	31/08/68	34.0N	59.0E	12 - 20,000	7.3	Destructive	
India	26/01/2001	23.3N	70.3E	19,988	7.7	Transform	
Kangra, India	04/04/05	33.0N	76.0E	19,000	8.6	Transform	
Turkey	17/08/99	40.7N	30.0E	17,118	7.4	Transform	

It is possible to identify much the same patterns of seismic activity in Europe. Whilst most earthquakes do occur at plate margins, a significant number do not (e.g. Norway and the UK). There is a considerable difference in the surface extent of earthquakes between different types of plate margin. Compare the Mid-Atlantic Ridge earthquakes with those at the margin of the Eurasian and African plates; it is clear that a much greater area is at risk from destructive margin earthquakes than from constructive margin earthquakes.

Table 1 lists the 'top twenty' earthquakes in terms of deaths since 1900. Notice that all the 'top twenty' earthquakes occurred either at destructive or transform margins; none were linked with constructive margins. This suggests that those places close to destructive or transform plate margins are likely to suffer much more from earthquakes than other places.

- ***Explaining the tectonic patterns***
  According to plate tectonic theory huge slabs of rigid 'plate' 100km thick are in constant movement, driven by convection currents originating deep within the Earth. Tremendous pressure builds up at the margins of the plates which, when released, causes a sudden jolt or earthquake. This accounts for the large number of earthquakes that occur at plate margins. The fact that the most deadly earthquakes occur at destructive and transform margins suggests that much greater pressures build up at these margins than at constructive margins.

Mid-plate earthquakes are more difficult to explain and have a number of possible causes including:
- Referred stress release, whereby stresses that build up at a plate margin are relieved along a mid-plate re-activated fault some distance away. The rare earthquakes in Britain are usually a result of fault movement.
- Reservoir construction, where increased weight and pore pressure re-activates an old fault.
- Water or oil abstraction (the later is probably a major factor in the Norwegian earthquakes in *Table 1*) altering underground pressures.
- Mining subsidence, for example coal mining in the UK and north west Europe *(Table 1)*.

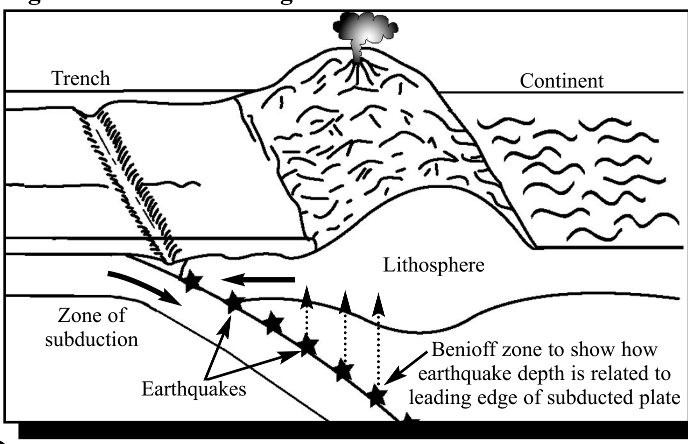
2. Earthquake magnitude and depth

The magnitude (or force) of an earthquake is measured using the Richter scale. This is a logarithmic scale that has no absolute limit. In terms of the release of energy, each value on the Richter scale represents a × 30 increase.

It is quite logical to expect that the stronger an earthquake, the more serious will be its effects. *Table 1* supports this assertion. With only one exception, the magnitudes recorded for the 'top twenty' earthquakes since 1900 exceed 7.0 on the Richter scale and the tope four disasters all exceed 8.0. However, the very fact that the magnitude values do not show a steady decline from 1st to 20th position in the table suggests that magnitude alone cannot be held responsible for the scale of an earthquake disaster.

Shallow earthquakes that occur close to the surface tend to result in a greater intensity of surface shaking and often cause the greatest loss of life and damage to property. Shallow earthquakes are often associated with destructive margins where the subducting plate descends at a slight angle thereby creating stresses close to the surface *(see Fig. 2)*.

Fig. 2 A destructive margin.



3. Nature of bedrock
Some materials are vulnerable to becoming 'jelly-like' when shaken – this is called **liquefaction** and it is commonly associated with clays and silts. The result of liquefaction is that building foundations become unstable and slopes become vulnerable to mass movement. Many buildings in Mexico City became tilted following the 1985 earthquake when the lake bed sediments on which much of the city is built became liquefied.

4. Population density
A natural event such as an earthquake only becomes a 'hazard' when it impacts on human activity. There is a considerable overlap between major earthquake zones and areas of high population density. Indeed many of the world's great cities lie in the heart of 'earthquake country', particularly around the Pacific Rim. These massive conurbations, which include the cities of San Francisco, Los Angeles, Tokyo and Lima, are especially vulnerable, with their densely packed buildings and raised freeways. Some 70 out of the top 100 largest cities in the world (10% of the world's population) lie in earthquake zones. It is surely only a matter of time before one of these great cities feels the full force of a mighty earthquake.

5. Building and structural vulnerability
A well-known saying states that "earthquakes don't kill people, buildings do". The vast majority of suffering results from the collapse of buildings or structures, such as bridges and elevated highways. In the 1989 Loma Prieta earthquake near San Francisco, 41 of the 67 deaths resulted from the collapse of the Nimitz Highway when the top storey of a double-decker freeway collapsed onto the storey below.

In wealthy areas where earthquakes are common, building materials and appropriate designs can minimise loss of life. This was certainly the case with the Loma Prieta earthquake where very few people were killed. However, despite the implementation of strict building regulations in recent decades, older properties remain vulnerable; it was the collapse of many such houses in Kobe, Japan in 1995 that led to the high death toll of over 6,300.

In poorer parts of the world building design is often inadequate and, although building design standards might be officially in place, regulations are rarely enforced. This was certainly the case in Mexico City when in 1985 several modern high-rise buildings collapsed as concrete crumbled and thin steel cables tore apart. The 12-storey central hospital collapsed like a pack of cards losing two thirds of its height as ceilings fell onto the floors below, crushing its inhabitants. In all, some 30,000 people were killed. In Turkey in 1998, some of the 20,000 buildings that collapsed killing 14,500 people were found to have seashells instead of pebbles in the concrete mix!

In areas where earthquakes are infrequent, precautions will understandably be very limited or even non-existent. It is in these areas often well away from plate margins where the suffering can be greatest. In 1993 a powerful earthquake measuring 6.4 on the Richter scale struck Khillari in central India. It was totally unexpected and the stone houses with their heavy insulating roofs collapsed killing some 10,000 people. Four months later, in January 1994, a slightly more powerful earthquake (6.6 compared to 6.4) hit the well-prepared city of Los Angeles killing just 40 people.

6. Extent of earthquake preparedness
This is closely linked to frequency of earthquakes and levels of development. In wealthy areas where earthquakes are common, such as California and Japan, much is done to prepare for the inevitable earthquake. There are regular earthquake drills in schools and offices. People are informed about potential dangers and how to respond when an earthquake happens. The emergency services practice their response procedures. Supplies of food, water, medicines and shelter are stored in recognised safe areas ready for coping with the aftermath of an earthquake. Education and preparation are undoubtedly factors in reducing the scale of a disaster, particularly regarding the response after the event in terms of rescuing injured people and avoiding the spread of disease. However, even the best laid plans can fail to live up to expectations as was the case with the Kobe earthquake when emergency teams reacted slowly and appeared to be totally overwhelmed by the scale of the disaster.

Poorer countries tend to be less well prepared. Whilst this is due in part to the lack of money to invest in preparedness materials and education programmes, it is also because earthquakes are often perceived as infrequent problems in a society facing daily struggles for survival of a much more mundane nature.

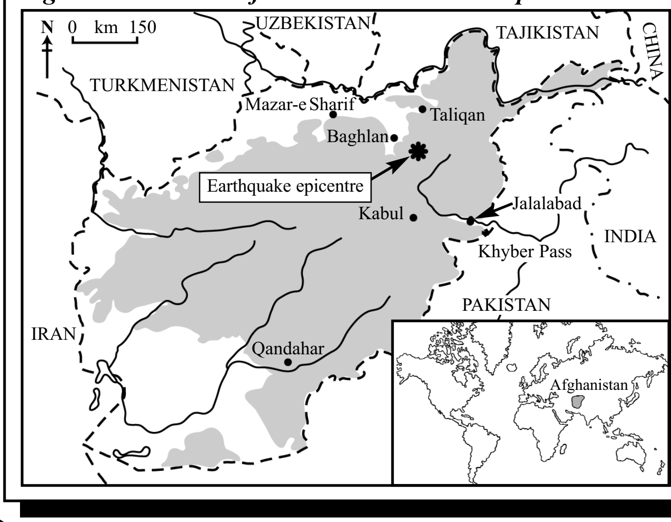
7. Levels of development
It is often said that LEDCs suffer much more from the effects of earthquakes than MEDCs and, whilst this is a generalisation, it is probably true at least in terms of the human costs. All things being equal, a poor country, with its less rigorous building standards and its inability to cope with the aftermath of an earthquake, will suffer greater loss of life, homelessness and loss of livelihood than a rich country. Media reports often focus on the apparently hopeless efforts of local people digging with their bare hands and moving rocks one by one in frantic attempts to locate victims buried beneath the rubble.

Table 1 supports this generalisation with most of the countries in the 'Top Twenty' being LEDCs at the time the earthquake struck. In recent years, some of the greatest earthquake disasters have occurred in LEDCs, including India (1993 – 10,000 killed), Afghanistan (1998 – over 6,000 killed by two earthquakes) and India again (2001 – 20,000 killed). Richer MEDCs do not tend to suffer quite so much human loss, but they do suffer massive financial losses as insurance companies and governments fund re-building programmes and pay compensation. The cost of reconstruction after the Kobe earthquake is though to be well over $100 billion!

Case Study 1: Hindu Kush, Afghanistan, 25th March 2002

A series of earthquakes lasting 10 hours killed 800 – 1,000 people, injured 4,000 and left approximately 20,000 homeless in a remote mountain region some 150km north of Kabul (Fig. 3). Entire towns were flattened by the earthquake which measured only a moderate 6.1 on the Richter scale. There were several reasons why such a moderate earthquake caused such widespread destruction:
- *The region is remote, war-torn and very poor. Afghanistan is one of the poorest countries in the world and recent droughts and wars have left it without the resources necessary to cope with the after math of an earthquake.*
- *The houses were generally inappropriate to withstand ground shaking, many with heavy roofs for insulation which simply collapsed burying their occupants.*
- *Although the earthquake was not especially powerful, it was a shallow earthquake occurring at a depth of 8km close to the boundary of the Eurasian and Indian plates, which are converging at a rate of about 4.5cm per year. A report published by the National Earthquake Information Centre in the USA states that "the earthquake of March 25 is another tragic example that shallow earthquakes cause more casualties and damage than intermediate depth ones".*

Fig. 3 The location of the Hindu Kush earthquake.



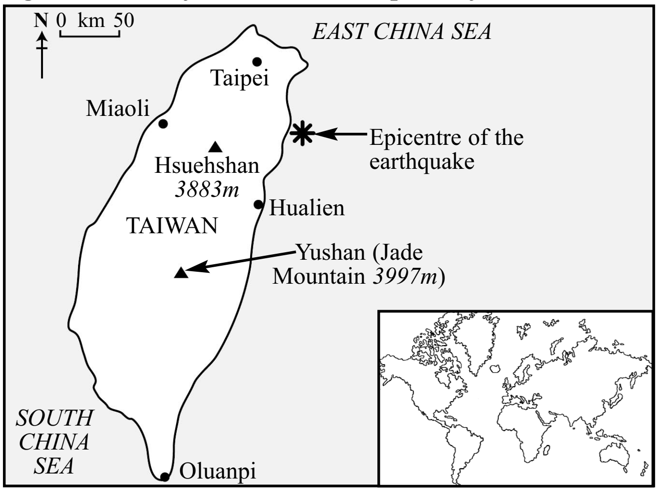
Case Study 2: Taiwan, 30th March 2002

A major earthquake measuring 7.1 on the Richter scale occurred near to the north east coast of Taiwan about 80km Northeast of Hualien (Fig. 4). The earthquake occurred in a tectonically active region known as the Taiwan Collision Zone where the Philippine plate, moving at some 7cm per year, is subducting beneath the Eurasian plate. The focus of what was considered to be a shallow earthquake was some 10km below the surface.

The earthquake caused the death of 5 people and injured more than 200, as fires were ignited and buildings cracked. Two crane operators and three other workers died when two cranes fell from their 60th storey perch at the construction site of the Taipei Financial Centre, due to become the world's tallest building when complete. Elsewhere, the earthquake and its 60 aftershocks caused landslides damaging property and severing roads.

The Taiwan earthquake was significantly more powerful than the Afghanistan earthquake yet it caused far less loss of life. There are several factors that account for this:
- *The epicentre of the earthquake was not particularly close to major built-up areas.*
- *The buildings, many of which are modern, coped well with the ground shaking. A news report in the Washington Post described apartment and office buildings swaying visibly. There was nothing like the widespread destruction of houses that occurred in Afghanistan.*
- *People were aware of the dangers and had prepared themselves appropriately to minimise injury and damage to property.*
- *Taiwan is significantly wealthier than Afghanistan and is therefore better able to prepare and then to react after an earthquake.*

Fig. 4 Location of the Taiwan earthquake of 2002.



Conclusion

As the many references to earthquake events in this Factsheet have demonstrated, the impact of earthquakes on human activity varies significantly across the world. This partly because the events themselves are unevenly distributed, both in terms of their geographical location and their magnitude, but also because people and societies have reached different levels of preparedness, in terms of building design and construction, and in their ability to educate people and respond after an earthquake event.

Two earthquakes of a similar magnitude might be expected to have similar effects on human activity, but this is often not the case. Perhaps more than anything else, it is the ability of a country to respond to earthquake vulnerability that determines the likely impact, and there can be no doubt that the MEDC/LEDC factor is paramount in this respect. Whilst there can be no doubt that tremendously powerful earthquakes will cause destruction wherever they occur, it does seem to be the case that, all things being equal, LEDCs tend to suffer more than MEDCs.

Further enquiries

1. Find out more about the two earthquakes that occurred in Afghanistan and Taiwan and try to discover in more depth why Afghanistan suffered more than Taiwan. There are several excellent internet sites, however the best place to start is the United States Geological Survey's 'National Earthquake Information Centre' at http://neic.usgs.gov. Click on 'Large earthquakes in 2002' and you will find reports on major earthquakes including Afghanistan and Taiwan.

2. Find out about the much more devastating earthquake that hit Taiwan in 1999. A general search for 'Taiwan earthquake' will reveal many excellent sites. Try to find out why there was so much more damage and loss of life in 1999 compared to 2002.

3. Access the 'National Earthquake Information Centre' at http://neic.usgs.gov and locate the 'Significant Earthquakes in 2002'. This will present you with an extensive listing of earthquakes which can be printed ('landscape' is better than 'portrait') and used to assess why some recent earthquakes, in terms of magnitude, plate margins, LEDC/MEDC and suggest any patterns. Is it the case that the greatest suffering occurs in LEDCs? Do high magnitude earthquakes result in the greatest loss of life? Do the most devastating earthquakes occur at destructive and transform plate margins?

Further research

There are a huge number of internet sites, far too many to list. The U.S.G.S.'s National Earthquake Information Centre (http://neic.usgs.gov) is excellent for objective and scientific information. For details of recent events, news agency sites such as the BBC (www.bbc.co.uk/news) provide good information and give many links. A general search is a good way as any to find information, although remember that accuracy about an event will only become apparent several days or even weeks after the event has occurred.

The 'earthquake hazard' is well dealt with in several recent textbooks, including:

Bishop, V. (2001) Hazards and Responses. Collins Educational.
Frampton, S. (Ed.) (2000) Natural Hazards. Hodder and Stoughton.
Nagle, G. (1998) Natural Hazards. Nelson Thornes.
Ross, S. (1998) Natural Hazards. Nelson Thornes.

Advanced reading

Use World Disaster Report – published annually by International Red Cross since 1993.
Bryant, E.A. (1995) Natural Hazards. C.U.P.
Smith, K. Environmental Hazards. Routledge.

Acknowledgements
This Factsheet was researched by Simon Ross – a well known author who is Head of Geography at Queen's School, Taunton.
Geo Press. *Unit 305B, The Big Peg, 120 Vyse Street, Birmingham B18 6NF*
 ISSN 1351-5136