HOW TO MAP AN EARTHQUAKE

Roger Musson
British Geological Survey, West Mains Road, Edinburgh, EH9 3LA, UK

When an earthquake has happened, usually the first question people ask is, "How big was it?" A seismologist will answer this question by quoting a value called the magnitude -- this is a number representing the amount of energy released by the earthquake. It's this number that is popularly referred to as the "Richter Scale". An increase of one unit represents a thirty-fold increase in energy, so an earthquake like the one that ruined Kobe in Japan in 1995 (magnitude nearly 7) was about 900 times as powerful as the earthquake felt across England on 27 February 2008 (magnitude about 5).

However, there's another question that can be asked: "How strong was it?" The strength with which earthquake shaking can be felt is very different from the magnitude, as it varies with distance from the epicentre of the earthquake. An earthquake may cause destruction near its epicentre, but as you go further away the damage becomes less and less. After a certain distance there will be no damage at all, but people will still feel the vibration, and even further away the shaking will be so weak people won't even feel it.

Earthquake intensity

Seismologists have always needed a way to measure how strong the earthquake was at different places, and this measure is called *intensity*. An interesting thing about intensity is that it's much easier to measure than magnitude. To calculate the magnitude of an earthquake, seismologists take measurements from a seismogram, which is a recording made by a measuring instrument, a seismometer. Although it is possible for an amateur with a knowledge of electronics to build his own seismometer as a hobby, professional instruments are expensive to buy and run. But measuring intensity is something that anyone can do.

Intensity is measured by something called an intensity scale, of which there are several different ones in use in different countries. The one used in the UK is called the European Macroseismic Scale. *Macroseismic* means "to do with the effects of earthquakes", as opposed to *microseismic* which means "to do with instrumental records of earthquakes (seismograms)". An intensity scale is simply a classification of the sort of effects that might be observed during an earthquake, with numbers increasing with severity. To find out the intensity value in a town during an earthquake, you just collect descriptions of what happened, compare them to the descriptions in the intensity scale, and choose the number that gives you the best match. The principle is exactly the same as that used for the Beaufort Wind Scale for measuring wind speeds.

The Earthquake Intensity Scale

A short version of the scale would go something like this:

Intensity 1: no-one at all notices the earthquake; the shaking is too weak.
Intensity 2: the shaking is so weak that only a very few people notice it, chiefly those lying down upstairs.
Intensity 3: a few people indoors (mostly upstairs) feel weak shaking, or notice a noise.

Intensity 4: many people indoors (especially upstairs) and a few outdoors feel shaking; windows, doors and crockery starts rattling.
Intensity 5: most people indoors feel strong shaking; a few are frightened and run out of the house; small objects like ornaments are knocked over; liquids splash out of containers.
Intensity 6: many people are frightened and run out; a few things fall off shelves; slight damage is done to houses -- bits of chimneys fall off a few houses; plaster is cracked.
Intensity 7: most people are frightened and some find it hard to keep standing; lots of things fall off shelves, and furniture is shifted about; many houses lose parts of chimneys and suffer considerable damage to plaster and cracks in walls.
Intensity 8: most people find it hard to stand; heavy items like TVs are thrown about and furniture is knocked over; many houses lose their chimneys completely and suffer severe cracks in their walls.

This is the highest intensity that has ever been observed in the UK (and not since 1884), but the scale goes on up to intensity 12, at which point everything is totally destroyed.

After an earthquake has happened, a seismologist will attempt to collect people's experiences and compare them to the intensity scale. Much of this information is collected using questionnaires, which can be used for doorstep interviews, or left for people to collect from libraries or post offices. Nowadays, most seismological agencies use online questionnaires that people can fill in via the internet. If the earthquake has caused damage, then a trip has to be made to the area where the damage occurred to record how bad it was.

All the information then has to be grouped by place once it has been gathered. One person's experience can vary greatly from another person's experience, even within the same house, so it is necessary to collect as many accounts as possible to see what the general experience was in that area. Typically one would give a single intensity value for all the accounts from a single village, but for a town or city, it might be necessary to give different values to the different suburbs. These could be quite different, because as well as the strength of shaking being affected by the distance from the earthquake, it's also affected by the local geology. If part of a town is in a river valley and part is on a rocky hill, the houses on the soft ground by the river will usually be shaken more than those on the hill.

Maps that show an earthquake

Once all the intensity numbers have been found, they can be plotted on a map. The Ordnance Survey 1:625 000 series makes excellent base maps for doing this in the UK (one can overlay the intensity values using tracing paper). The resulting map gives a complete picture of the effects of the earthquake. For more detailed studies of small areas, 1: 50 000 maps can be used.

Usually the seismologist will then want to draw some contours for the different intensity values. This is not always simple, as the numbers are often jumbled about on the map; partly due to the changes in geology over short distances. Each contour is drawn in such a way as to enclose as many places as possible that have the same intensity, while not including too many that have a lower intensity, and trying to keep the curves smooth. The resulting lines are called *isoseismals* (lines of equal shaking). Usually these lines tend to form ellipses.

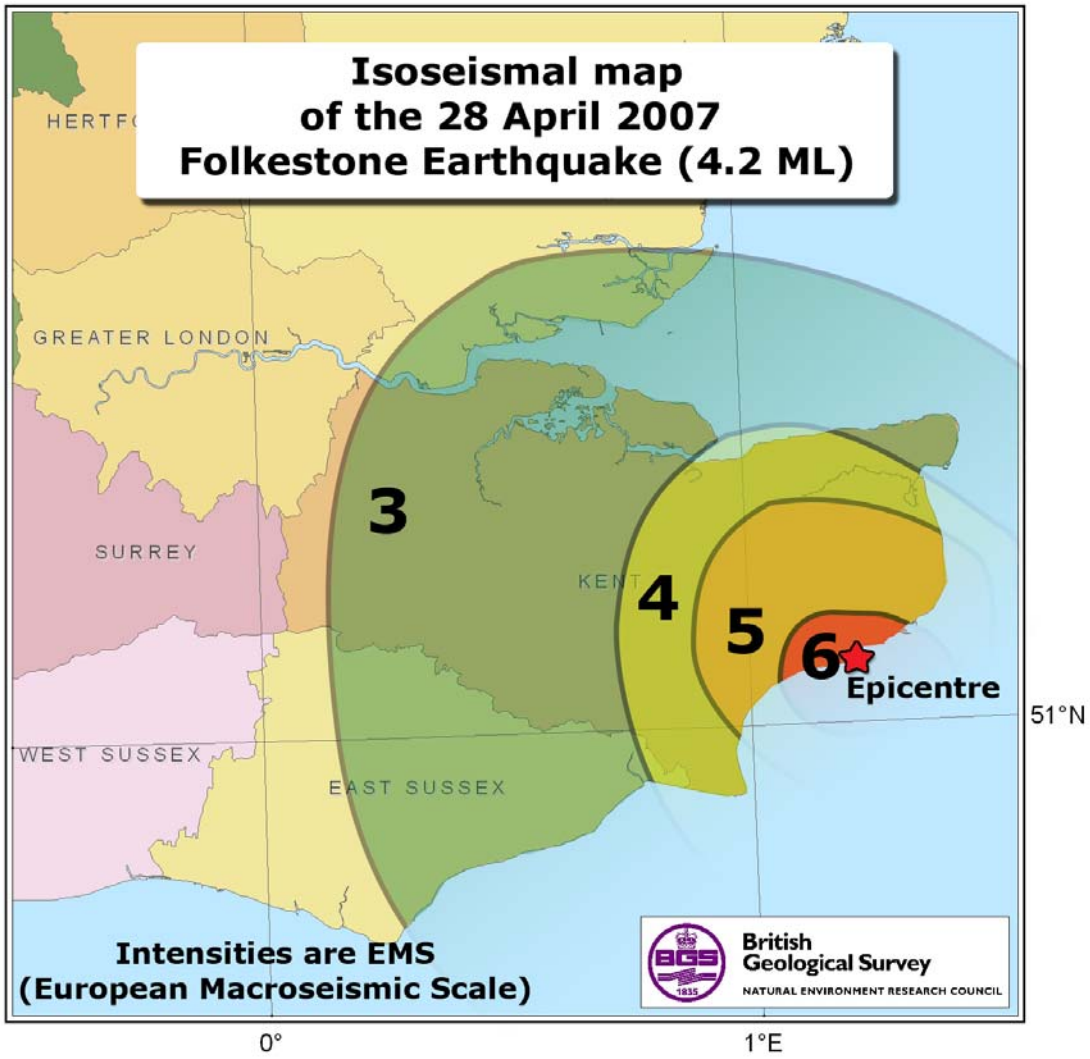

Figure 1 - Isoseismal map of the 2007 Folkestone earthquake

An example of an isoseismal map for a recent British earthquake is shown in Figure 1. Such maps are useful for two reasons. Firstly, they can be used to work out what sort of effects can be expected from earthquakes in the future, when one knows how rapidly the shaking decreases with distance (this is called *attenuation*). Secondly, you can actually work out some of the other statistics about the earthquake from the isoseismals. For example: measure the area enclosed by the isoseismal for intensity 3 (in square kilometres) for a British earthquake. Take the logarithm of this number. The result is equal to the magnitude (more or less)! And the position of the epicentre can be found by taking the centre of the innermost isoseismal.

Using this it's possible to find the magnitude and epicentre of earthquakes in historical times that happened way before the invention of recording instruments (which was a little before 1900, but it wasn't until the 1960s that they became sensitive enough to record small British earthquakes). The procedure is much the same: collect as much data as you can about the earthquake (old local newspaper reports are a good source of information), then sort the data by place, work out the intensities, make an isoseismal map and take your measurements. This was the method used for constructing the historical part of the national catalogue of earthquakes in the UK. A map of this catalogue is shown in Figure 2; you can see that some parts of the UK are much more active than other parts.

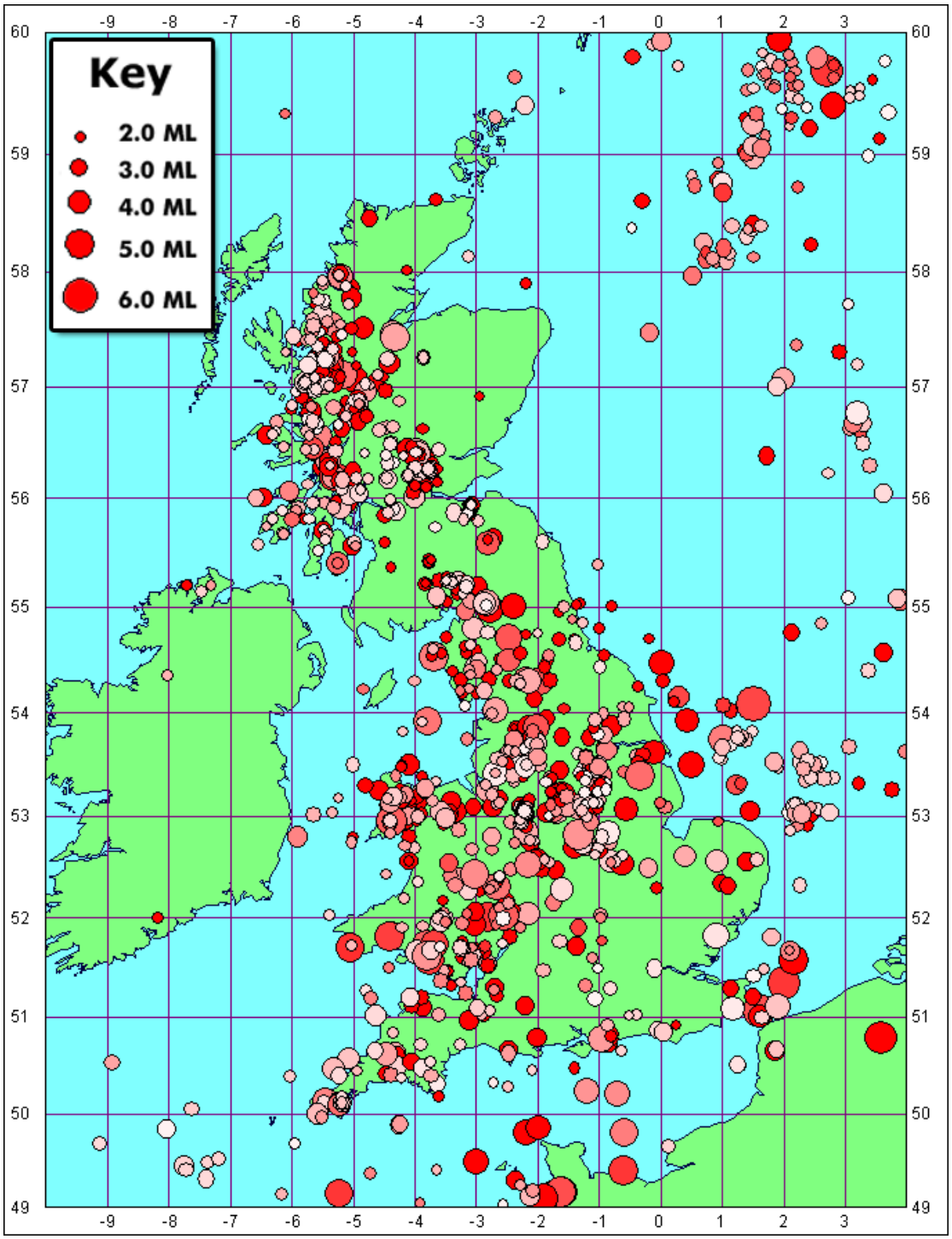

Figure 2 - Seismicity map of the UK; symbol colour indicates depth of focus (lighter = shallower; full red = depth unknown)

You can do it too

This sort of study makes an ideal school project, should there happen to be an earthquake in your district. If the earthquake is small, you may be able to collect data for the whole of the area affected by it; even if this isn't possible because the felt effects cover too wide an area, it is still interesting to collect data for the area around

the school and see how much variation in effects occurred. Can you see a decrease of strength of shaking from one side of the area to the other? Can you see variations that are a result of local geology? Also, any data collected by schools can also be passed on to the national investigation of the earthquake effects, which in Britain is organised by the British Geological Survey. You can get more information at this address: http://quakes.bgs.ac.uk/index.html

Alternatively, if you don't want to wait for the next British earthquake (and the ones large enough to be felt over a reasonably wide area are not all that frequent -- we might get one a year) - it's possible to make a study of some earthquake that happened in the past that affected your area; you may find enough historical data in your local library, especially if it has files of the local newspapers.

An isoseismal map is like a snapshot of a whole earthquake, summarising in one picture everything that happened over a wide area. Such maps are very helpful to seismologists, who use them frequently; yet their construction requires no special equipment and can be done by anyone with an interest.

More information on earthquakes

The map of earthquakes in the UK in Figure 2 is an update (as of July 2008) on the one in the book *Earthquakes -- our trembling planet* by Susanna van Rose and Roger Musson. This is an Earthwise publication, ISBN 0 85272 287 7, available from the Sales Desk, British Geological Survey, Nottingham, NG12 5GG (tel 0115-936-3241, fax 0115-936-3488) or it can be ordered from bookshops, price £6.50. This book gives a general introduction to the study of earthquakes, their causes and effects, as well as having information on British earthquakes. It is suitable for Earth Science students at key stage 4 and A level. A complete guide to British earthquakes is also published by BGS: *A catalogue of British earthquakes* by Roger Musson (BGS Report No WL/94/04) is available from the address above, price £15.