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JAPAN 2011: EARTHQUAKE, TSUNAMI, NUCLEAR CRISIS ...

The series of hazardous events that hit Japan in March 2011 involved a set of complex and interrelated factors, some physical and some of human origin. The result was perhaps the worst disaster to befall Japan since the Second World War.

The seabed off the eastern coast of Japan is a highly seismologically active section of the earth's crust (Figure 1). The Eurasian, Pacific and Philippine plates meet here, making it an extremely complex boundary. Japan experiences 20% of the world's earthquakes of Richter Scale magnitude 6 or greater. On average, an earthquake – usually of low intensity – occurs every five minutes. Local people expect a larger tectonic event on average every 40 years, but the sheer scale of last March's earthquake shocked the population and emergency services.

Japan is located on the eastern edge of the Eurasian plate, adjacent to the huge, very solid Pacific plate. The Pacific plate is moving westwards, towards the Eurasian. As the denser of the two, the Pacific plate dips beneath Japan, rather like an escalator. The rate of movement is 7.6–10.2 cm per year. The situation

Figure 1: Plate boundaries in the Japan region

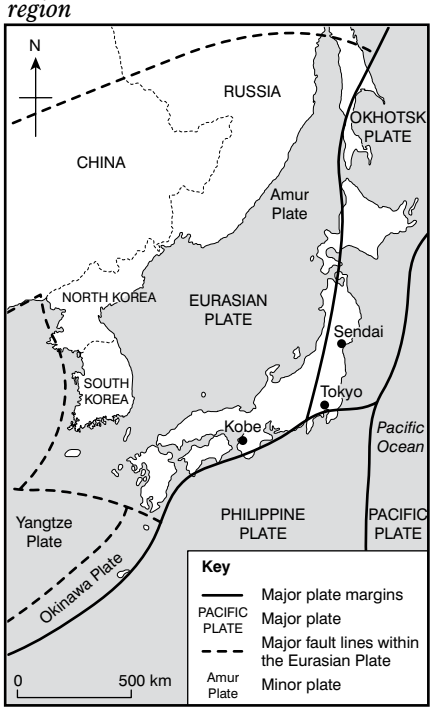
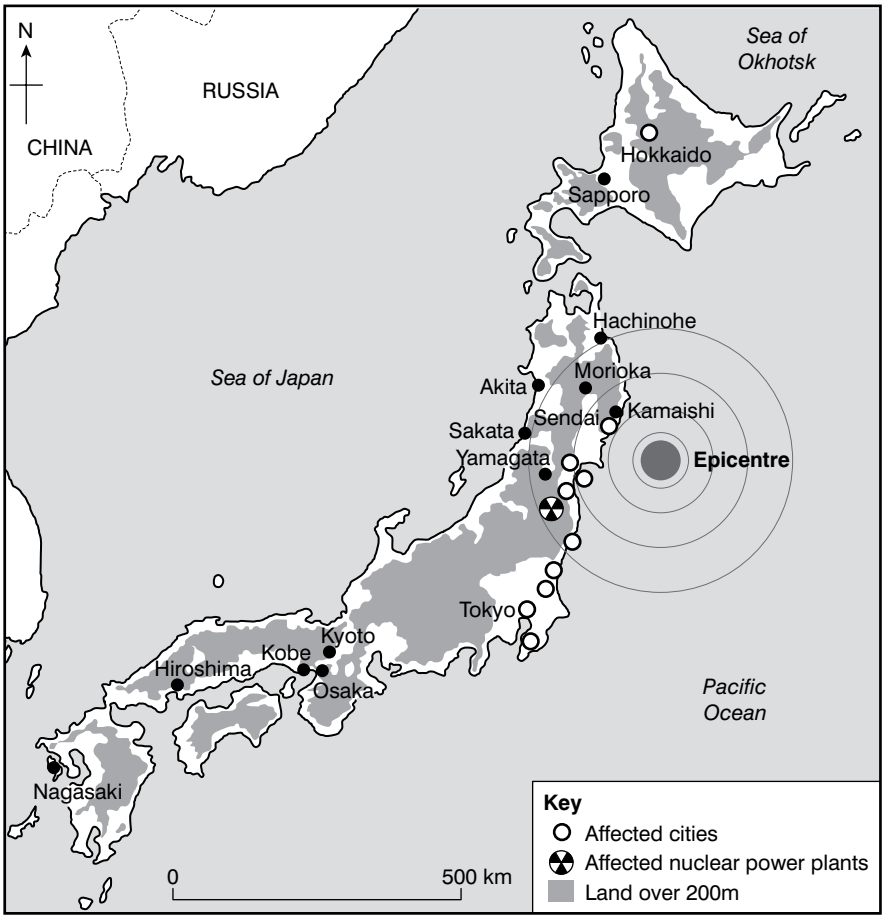


Figure 2: The earthquake epicentre, showing the affected cities



is complicated by two things. First, there are two other plates in the equation: the Okhotsk to the north and the Philippine to the south; secondly the make-up of the eastern part of the Eurasian plate is complex in itself, as it includes several large fault lines. Some geologists see these as true plate margins (Figure 1).

Wednesday 9 March 2011 saw a 7.2 (Richter Scale) earthquake on this plate boundary. This level of event is not unusual, but, on this occasion, the knock-on effects were particularly serious, as the push of the Pacific plate as it went under Japan put extra strain on an area of existing pressure build-up along the margin. This led directly to a 480-km stretch of the Pacific plate breaking free and surging underneath Japan. At the same time, the Eurasian plate (on which Japan is situated) shifted 2.4m eastwards and was simultaneously lifted upwards by over 9m. The consequence was the 9.0 (Richter Scale) Tohoku earthquake on 11 March, rated as the fifth most powerful ever recorded globally (Figure 2). People do not always perceive the massive variations in the strength of Richter scale readings. Each point on the scale has 10 times the energy of the point below. Therefore, this second earthquake released around 1000 times the energy of the event along the margin two days previously, equivalent to around 600 of the Hiroshima atomic bombs dropped at the end of World War II. This would have been an epic disaster on its own, but then the tsunami hit!

The tsunami event

Japan experiences more tsunamis than any other country. The word means 'harbour wave', and has been adopted worldwide for such events. Several factors determine the height

and therefore the destructiveness of a tsunami:

- the scale of the earthquake
- the volume of displaced water
- the topography of the sea floor
- whether there are any natural obstacles that dampen the shock and absorb some of the energy.

Ultimately, the tsunami was concentrated on a limited stretch of coastline around Sendai.

Since the epicentre was located under the ocean floor, all the water above this point was suddenly pushed up vertically, and therefore surged away in all directions at a speed of 800 kph (500 mph), the speed of a jet aircraft, across the Pacific in all directions. It took a mere 10 minutes for the wall of water to reach the coast of Japan. The speed and height of a tsunami wave are determined by the depth of the ocean. The shallower the water, the slower but higher is the wave. Where, as in this part of Japan, the offshore area is particularly shallow, friction between the moving water and the seabed slows down the lower part of the wave. The following water is then held back, so a sort of 'traffic jam' of water develops, causing the tsunami wave to build up higher and higher; in this case it was believed to have reached 40m in some places, completely overwhelming for people and for both natural and built environments. Whole settlements on the coast were simply erased in a few moments, as water flowed 10km inland. Sendai airport was rendered unusable within minutes, limiting future aid accessibility (Figure 3).

Source 1: Japan's disaster in figures – the impacts of the tsunami and subsequent crisis at the Fukushima nuclear power plant

- Japan's National Police Agency confirmed 15,676 deaths, 5,712 injured, and 4,832 missing.
- Victims aged 60 or older accounted for 65.2% of the deaths; 24% of victims were in their 70s.
- 45,700 buildings destroyed and 144,300 damaged. 300 hospitals damaged, with 11 completely destroyed. An estimated 24–25 million tons of rubble and debris.
- Around 1.5 million households without water supplies and 4.4 million without electricity.
- People within a 20-km zone around the Fukushima nuclear plant ordered to leave, those living between 20 km and 30 km from the site requested to stay indoors and subject to voluntary evacuation: >200,000 evacuated.

Evacuation and coping strategies

Finding those who needed rescuing was an extremely difficult challenge. Landline telephone connections were immediately lost at the point of the earthquake jolt, which also disabled most mobile phone masts. Electricity was also cut off, so those mobile phones which could get a signal soon had spent batteries. When homes and other buildings collapsed, people on the upper floors fared better, but often their only way out was to be rescued through the roof. An extensive area of north-eastern Japan was affected and there were simply not enough emergency workers to cope. Local police were usually the first on hand, but rarely had access to large equipment.

The frustrations of the rescuers

The chaos of the early hours and days of the rescue process are well illustrated by the reports directly from the rescuers themselves. They had come from the south of the country, Nagasaki and other cities, to find there were very few supplies of any kind for them to work with. Instead of administering medicines they were reduced to trying to ensure people washed their hands as often as possible to prevent colitis, enteritis and diarrhoea. The risk of flu passing between the elderly and weak was huge.

Within 10 days of the earthquake, an estimated 452,000 people were living in evacuation facilities, most of which were inadequate, leading to huge numbers suffering from hypothermia. Accommodation for those who had lost their homes was largely in schools and other public buildings, whose heating and other services were cut off. Often damp from floodwater, people had to cope with the bitter cold with a few blankets if they were lucky. In one residential home alone, 11 elderly people had died of this within a few days due to night-time temperatures as low as -4°C. Dampness made the impact of the cold much worse. Bronchitis, pneumonia (both of which require antibiotics) and asthma (which needs sprays and other equipment) made the lives of hundreds even more difficult. Many chronically ill people, such as those with diabetes, could not get the medicines they needed. Even amongst the fitter of the population, hardly anyone directly affected by either the earthquake or the tsunami got away without broken bones, cuts or bruises.

The likelihood of epidemics breaking out, especially amongst the most vulnerable groups (the elderly, children and those already suffering from illness or infirmity) was high. Doctors and hospitals did all they could to care for those who required

Figure 3: Sendai airport, two days after the tsunami

Source: Wikimedia Commons

it, but they were short of medicines and personnel. Even emergency workers brought in from elsewhere in Japan were not always able to help as much as many people expected.

Cases of enteritis, colitis, diarrhoea and vomiting grew rapidly. Any epidemic would be most dangerous to the elderly survivors, already vulnerable by dint of age, and much affected by the experience of the disaster.

Damage to roads, railways and airports severely impeded transport following the disaster. For quite some time it was very difficult, even with military help, to deliver medicines and food to the affected area. Homeless survivors of the tsunami, temporarily housed in hospitals and schools, were given only very meagre supplies of rice and tea for some time. In some cases, they were driven to scavenge in the wreckage of their townships, picking among debris for provisions that had been swept away from shops by the tsunami, taking a chance that it was not contaminated – behaviour that would normally have been unthinkable and shameful. Shame plays an important role in Japanese society. Natural disasters strip away the dignity of both the living and the dead, but in a country as polite and formal as Japan this is particularly poignant.

In the town of Ichinomaki one supermarket remained open, but the queue was 2 to 3 hours long, people were allowed only 10 items or fewer, and they had to pay in cash. Most people had lost their cash and debit/credit cards when they lost their home.

Japanese pride

People were scavenging in the streets to try to find food for their families. They took what seemed like waste food from devastated supermarkets even though there were health risks from thawed frozen and out of date products. People found themselves without money, food and other resources, and their homes had been washed away and the cash machines were out of order. You too would probably have done the same as them in equivalent circumstances.

The extra difficulty for the Japanese in this awful situation was their culture of pride. Your reputation in society is very important to the Japanese. Just to be caught taking food or other crucial resources could blacken your name and diminish your family. Yet, even in an MEDC like Japan, many people had to become looters to stay fed, even at a limited level. Even those lucky enough to be in rescue centres were not necessarily fed enough in terms of quantity, calories or nutrition. People felt genuine shame at what they were doing and, whilst some did speak to foreign press, they refused to give their names or to have their photographs taken.

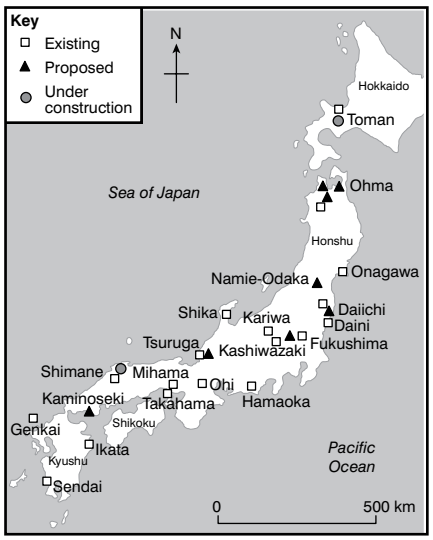
The local authorities found themselves under massive strain. The rules on burial procedures had to be relaxed to permit the burial of bodies without prior cremation, not the normal ritual in Japan, but essential on health grounds. Emergency workers coming to the affected north-eastern part of the country had insufficient knowledge of the situation, inadequate equipment and basic supplies like food, clean water and medicines. Whilst many roads in the north-east region were devastated, quite a few remained open, but only emergency vehicles were allowed to use the roads, so preventing food supplies, fuel and other aid from being driven from Tokyo. Finding petrol and diesel became impossible; people siphoned it from vehicles damaged in the tsunami and tried to find lost bicycles in the piles of wreckage. People struggled to find missing friends and relatives in any way they could (Figure 4).

Nevertheless, many people refuse to criticize the local or national authorities, realizing that the sheer scale of the destruction had made delivering aid a truly mammoth task.

The nuclear power station crisis

'Japan hails the heroic "Fukushima 50",' read a headline from Japanese newspapers, referring to the 50 volunteer nuclear power station and other engineering workers who remained within the stricken Fukushima site (Figure 4) battling to cool down the system and avert widespread radioactive leakage. They were likely to have been exposed to doses of radiation 12 times the legal limit in the UK, which in the short term should

Figure 4: Nuclear power plants in Japan



cause little harm. In the longer term, however, there is an increased likelihood of cancer.

Nevertheless, the Fukushima Daiichi nuclear plant disaster brought on by tsunami damage was one of the most serious civil nuclear accidents to date. Key safety systems failed, causing serial explosions and increasing releases of radiation. Four of the plant's six reactors were in trouble; higher than normal radiation levels were registered as far away as Tokyo (220km) but were not considered serious. Caesium and iodine isotopes have been found near the plant, and water and crops were prevented from entering the food chain. Local people (within 20km of the plant) were evacuated, and others left of their own accord. Compared with Chernobyl's disaster in 1986 (Ukraine), only 10% as much radiation was released.

It was not until November 2011 that reporters were allowed inside the Fukushima nuclear power plant. Fully protective clothing was essential. Requests for such visits had previously been refused on the grounds that radiation levels were simply too high and that the presence of visitors might limit the progress of the clearing up operation. The intention of allowing a tour at this stage was to show that the plant is indeed becoming more stable. Visitor reaction was mixed and you would expect journalists to be naturally suspicious. There were reports that some badly damaged buildings and piles of rubble had

Source 2: The Japan Tsunami Appeal

- The Japanese Red Cross opened its appeal for aid funds within hours of the disaster taking place. British people could donate via the British Red Cross. The aims were:
- First aid and emergency healthcare
- Distributing relief items
- Fitting out 70,000 temporary prefabricated homes with key appliances and domestic items (rice cookers, microwaves, kettles, etc. for 280,000 people in the hardest hit prefectures of Miyage, Fukushima and Iwate.

not yet been cleared, nor had all the damaged vehicles.

A report published in the Proceedings of the National Academy of Sciences in November 2011 stated that radioactivity levels across much of the North Eastern region of Japan remained higher than that considered safe for farming, despite the fact that earlier testing had showed that harvested crops contained levels of radiation well below the safety limit for human consumption. The source of the radiation was the radioactive isotopes (in particular caesium) that were blown across this area and offshore when the Fukushima plant melted down. Waves continued to wash some of this radiation back onshore in the east over the following months and scientists are uncertain as to how long this might continue. The western coastal plain region measures safe levels; it was largely protected from the worst of the radioactive fallout by the intervening mountain ranges.

The Japanese will continue to monitor this problem thoroughly. Whilst it seems certain that the Fukushima region remains contaminated, detailed checks need to be carried out in the neighbouring prefectures of Iwate, Miyagi, Ibaraki, Chiba, Yamagata and Niigata. Rice exports from this region to the rest of Japan have been banned, though some may have been consumed locally. Scares over radiation levels in green tea, mushrooms and beef have occurred.

Only time will tell the true consequences of this event.

All other nuclear plants will be strength-tested for tectonic movement. Moreover, the Japanese authorities have been made to think about the country's future energy mix. Current policy is to increase from 30% of power being nuclear-generated to 50%, but now the likely future trend is away from nuclear, perhaps even to go nuclear-free in such an active tectonic zone. Strategies for energy conservation and development of renewables will grow. There is even a plan to construct a 400-km wide belt of solar panels around the moon's equator, and beam the energy back to Japan using laser-guided microwaves.

The current Japanese tectonic situation

Japan is used to earthquakes. In March 2011 the greater crisis was the tsunami and, in particular, the proximity of the epicentre to the Japanese coastline. Japan has experienced earthquakes and their consequences throughout recorded history (and, clearly, before). It will continue to do so, due to the highly active tectonic nature of the region, on a quadruple tectonic junction. The area of greatest concern is currently Tokyo, sitting right on top of a triple junction and with over 20 million people in the city. The last earthquake to hit Tokyo (in 1923) killed 142,000 people in what was then a much less populous zone. Moreover, geologists and seismologists believe this area to be overdue for an earthquake. Pressure is building up underground. Just as the magnitude 7 earthquake of 9.3.11 increased the strain under the plates, leading to the magnitude 9 event two days later, so the level 9 'quake could have built up extra pressure under Tokyo.

Conclusion

When studying hazards and their impacts on countries at varying levels of economic development, we tend to make the assumption that LEDCs are affected much more than MEDCs. This is largely true. The 1989 Loma Prieta earthquake in California (around 7 on the Richter Scale) killed only 62 people and damaged relatively few buildings seriously. Yet the cleaning-up operation after the 1995 Kobe earthquake is still not complete and there are people suffering financial losses from which they can never recover, due largely to their lack of insurance. The Sendai earthquake event, along with its tsunami, was even more devastating than Kobe. Not every building, even in an MEDC, can be earthquake-proof, and no technology to date can protect against such a severe tsunami. Neither can the wealthiest and most organized governments cope with all that is required on such a short timescale: 'I thought we were a wealthy country, but now I don't know what to think', was a typical Japanese citizen's reaction. The Japanese refused much external aid that was offered, though some was accepted (Source 2).

Focus Questions

Using Figure 1:
(a) Describe the pattern of plate margins in the Japan region.
(b) Explain why the region is so hazard-prone. (Hint: remember there are human factors as well as the more obvious physical ones.)

2. Using Figure 2:
(a) Briefly describe the settlement pattern in Japan and explain the pattern you have identified in terms of the physical landscape. (The map has enough information on it to allow you to do this.)
(b) Explain why Sendai was particularly badly affected. Use map evidence to support your points.

3. Essay: Discuss the extent to which the Japanese people both help and hinder themselves in hazard prevention and in coping after a disaster such as the Sendai event of March 2011. (You should include references to other relevant tectonic events such as Kobe (1995) and to volcano/earthquake precaution methods and warning systems.)