Shock wave

13 Jan 2005

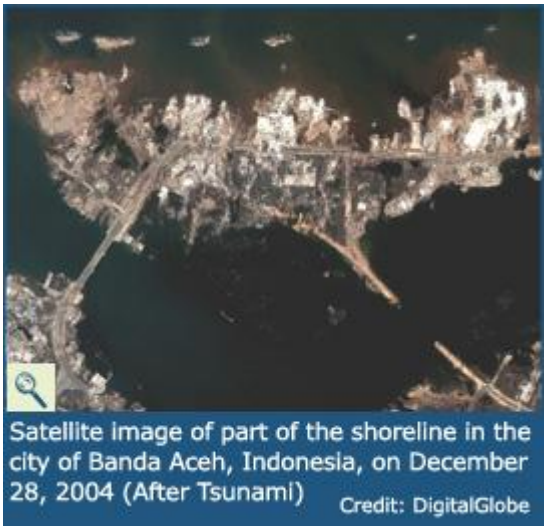
On Sunday 26 December 2004, a Magnitude 9.0 earthquake occurred off the West Coast of Northern Sumatra in the Indian Ocean. The world's strongest for forty years, it generated a massive tsunami that is known to have claimed around 300,000 lives. *Animation credit: NOAA*

Surrounded on all sides by heavily populated continental edges and islands, the spreading wave hit Indonesia and Thailand within an hour, and then Sri Lanka and India, ultimately reaching as far as eastern Africa. The deaths were counted across a dozen countries, with the Indonesian island of Sumatra losing 100,000 people. It is the worst disaster to have struck the region since 1883, when Krakatoa exploded, killing 36,000 Javans and Sumatrans. The event has highlighted the vulnerability of the growing population of coastal Asia and Africa. It has also raised important questions about the effectiveness of human societies in dealing with such extreme high-magnitude events – in terms of levels of preparation, the effectiveness of warning systems and the ability of the international community to act unilaterally to quickly organise an effective response.

What was the cause of the tsunami?

A tsunami is a large, seismically generated sea wave which is capable of considerable destruction in certain coastal areas. The wavelength in the open ocean is of the order 100 to 150km and the rate of travel of a tsunami is between 640 and 960 km/h. December's tsunami was caused by a giant earthquake where one of the earth's major tectonic plates – the Indo-Australian plate – collides with the smaller Burma microplate at a rate of about 6 cm/year. At this destructive plate boundary, the denser Indo-Australian plate is subducted beneath the overriding Burma plate. Driven by convectional currents in the earth's mantle, this movement is responsible for producing deep-focus earthquakes that can force the ocean floor upwards, generating tsunamis.

Satellite image of part of the shoreline in the city of Banda Aceh, Indonesia on June 23, 2004 (Before Tsunami) Credit: DigitalGlobe



Satellite image of part of the shoreline in the city of Banda Aceh, Indonesia, on December 28, 2004 (After Tsunami) Credit: DigitalGlobe

A build-up of pressure over recent decades caused the floor of the Indian Ocean to suddenly lurch some 15 metres towards Indonesia, diving under the Burma microplate, displacing it upwards. The journal *Nature* explained that 'the earthquake followed almost two centuries of tension during which the India plate pressed against the Burma microplate, which carries the tip of Sumatra as well as the Andaman and Nicobar Islands. The plates move against one another at an average rate of about 6 centimetres a year, but this movement does not occur smoothly. There has not been a very large quake along this fault since 1833 — a fact that may have contributed to the huge force of this one. The

India plate's jarring slide released the tension on the Burma microplate, causing it to spring violently upwards.'

Described by the U.S. Geological Survey (USGS) as a *megathrust* earthquake, the scale of this Magnitude 9.0 event was stunning. A 1200 km stretch of the plate slipped, and it is likely that the average displacement on the fault plane was about fifteen meters. The actual rupture duration on the fault (the time it took for the earthquake to take place on the fault and rupture the entire length) was approximately 3 to 4 minutes. During this time, the earthquake released energy that was the equivalent of 23,000 Hiroshima bombs.

As a result, the sea floor overlying the thrust fault was uplifted by several meters and it was this sudden change in ocean depth that generated the tsunami, as a trillion tonnes of water overlying the upwardly-moving plate was vertically displaced. This produced a long, low-amplitude wave travelling at up to 900 kilometres per hour in all directions away from the earthquake's epicentre. Wherever the wave reached shallower water near a coastline, it shortened as friction interfered with the elliptical orbit of the moving water. As it slowed, it gathered into surges that came crashing down on populated coastal areas.

What factors determined the impact of this hazard?

The cost of the tsunami, both in terms of human lives and also in financial terms, is immense. It is the fourth worst natural hazard to have occurred globally within living memory, exceeded only by past flooding along China's Yangtze River (1931, 1975) and the Bangladesh coast (1970). A physical event of such immense magnitude clearly has the potential to cause great damage. However, human factors always co-determine the actual *impact* that a hazard has on society, as follows:

Satellite image of Gleebruk Village, Indonesia, on April 12, 2004 (Before Tsunami) Credit: DigitalGlobe

Satellite image of Gleebruk Village, Indonesia, on January 2, 2005 (After Tsunami) Credit: DigitalGlobe

(1) Population density and distribution Parts of the region are very densely populated after several generations of rapid population growth (caused by high fertility but falling mortality). India and Indonesia have the world's 2nd and 4th largest populations, respectively. Migration has then brought many of these people to coastal regions in search of work. Hence, the risks associated with potential tsunami damage in the Indian Ocean were much higher than in the past (in comparison, the 1964 Magnitude 9.2 earthquake in sparsely-populated Prince William Sound, Alaska, killed very few). Population is also spread across many small islands chains such as the remote Andaman Islands that were hard to contact in the aftermath of the disaster, thereby hindering aid efforts. The difficulties in beginning to co-ordinating relief efforts are reflected in the amount of time it took to actually gauge the true death toll, given the highly dispersed nature of the region's population. For instance, on December 27th, *The Daily Telegraph* suggested 'more than 12,000 people' were dead. By 29th December, *The Independent* claimed that there had been 60,000 victims. By 2nd January, *The Observer* newspaper was reporting 150,000 deaths.

(2) Inadequate warning systems and preparation Advance warning of hazards - even if it is only a matter of hours or perhaps minutes - can drastically reduce mortality rates. The successful collection and dissemination of information is therefore vital. Although earthquake scientists knew about the Magnitude 9.0 earthquake within minutes, the absence of monitoring equipment in the ocean itself meant that they did not know whether a tsunami had occurred. Additionally, the region lacks effective warning systems. Thus, even if the tsunami had been spotted sooner, it is uncertain whether effective warnings could have been made (and in LEDCs, many people do not have access to TV or radio, making it difficult to warn remote villages). The event has highlighted the lack of a system to warn Indian Ocean populations of an imminent occurrence of a tsunami. In contrast, the Pacific Tsunami Warning Center has been responsible for tsunami monitoring in the Pacific Basin since major earthquakes struck in Chile in 1960 and Alaska in 1964.

(3) Time of year The tsunami struck on Boxing Day, when numbers of tourists (particularly those from northern and western Europe) were higher than at many other times of the year. This may well have raised the final death toll.

You can download excellent image analyses of the satellite imagery of Sri Lanka and Indonesia from the DigtialGlobe website:

Banda Aceh Image Analysis

Gleebruk Image Analysis

Meulaboh Image Analysis

Sri Lanka Image Analysis

What happens next?

Longer-term developments that geography students and their teachers may want to keep an eye on include:

(1) Secondary hazards Major concerns now exist over the possible spread of disease, particularly in places where fresh water supplies have been contaminated. A major cholera outbreak would constitute a secondary hazard that might send death tolls spiralling even higher.

(2) Aid efforts Already, newspapers and television are reporting the more controversial aspects of emergency aid efforts to help the region (see The Guardian, 29 December 2004, for instance). Large amounts of money have been pledged by governments, NGOs and the populations of many developed (and developing) nations. Yet it is proving difficult to co-ordinate a relief operation of this scale. Will this later be seen as a triumph, or failure, of governance?

(3) Tourism Countries such as Thailand have been depending heavily upon tourism as a development strategy, hoping to build a multiplier effect around 'honeypot' destinations such as Phi Phi. What will be the long-term effect on tourist numbers?

(4) Hazard management The human failure to predict, warn and evacuate will certainly be addressed in the aftermath of the tsunami. For instance, a seismograph designed to detect the earthquakes that cause tsunamis was installed on the Indonesian island of Java in 1996, but the data it collects is not sent to the central government in Jakarta because the telephone line has been disconnected since an office move in 2000! The need for a system in the Indian Ocean has been discussed at regular intervals by the Intergovernmental Oceanographic Commission, the UN body that runs the Pacific network, since at least 1999. The most recent meeting of the Commission to discuss the threat was in June 2004, although no direct action was decided upon. The UN International Strategy for Disaster Reduction has now said that one should be built within a year.

AS / A-level notes

It would be surprising if candidates taking geography exams this year did not want to discuss the causes and consequences of this dreadful episode in various contexts perhaps when writing about earthquakes, hazard management, sea-level rises, international aid efforts, refugees, tourism or many other related topics. As a basic guideline, here are a couple of academic areas where good knowledge of recent events in the Indian Ocean ought to be on display:

(1) Earth systems This event reminds us how much earthquakes can vary in terms of both their size and impact. Consider the deceptively simple question 'what are the impacts of earthquakes?' Candidates might emphasise that small shallow-focus earthquakes associated with divergence at the mid-Atlantic ridge cannot equal deep-focus subduction earthquakes in terms of their potential for damage. The world's largest recorded earthquakes have all been megathrust events, occurring where one tectonic plate subducts beneath another.

(2) Hazard causes, impact & management With so much media coverage, there is no shortage of information dealing with the management failings that have come to light in the Indian Ocean region. However, when writing about hazard management, it is important to stress the varying *scale* of natural hazards. While small-scale events – such as this summer's flooding in Boscastle Cornwall - can be effectively managed and perhaps even prevented, the sheer scale of the Indian Ocean tsunami and its unpredictability mean that major losses of life were always inevitable.

Teachers Links

Staffordshire Learning Net geographers have responded to the tsunami disaster by creating resources to help pupils understand and make sense of the events. There are resources, also, for Post-16 geography

Geographical Association materials for supporting the sequence of lessons and activities on the tsunami disaster

Teacher Resource Exchange resources related to the Indonesian earthquake and tsunami

Geography Pages has S.E. Asia Tsunami weblinks and resources

Geointeractive downloadable resources for teachers on the tsunami disaster

Juicy Geography has a short discussion paper for KS3/4 which examines the problem of drifting media coverage, broken government promises, different phases of aid, long term aid and the role of individual citizens

Geo-World - A *special report* and interactive website on the Asian Tsunami

Oxfam Cool Planet - *Tsunami in Asia* brings together educational materials from Cool Planet, and information from the main Oxfam website and external sites, to enable teaching around the current humanitarian crisis in Asia.

Guardian - how to cover the subject of tsunamis

Global Dimension - links to tsunami resources

Teachers in Development Education - Responding to the Tsunami

Other tsunami resources and links

Guardian - interactive guides to the tsunami

USGS – Earthquake in the News

The Times - How the shape of ocean floors can affect speed and height of tsunami

The Why Files - warming to a warning system

Wikipedia - Strongest earthquake in 40 years hits Southeast Asia

Collection of videos of the tsunami

Satellite images from DigitalGlobe

Tsunami blog