Geo Factsheet

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The Italian Earthquake 2016

The Central Apennines is a very tectonically active region of Italy, and in recent years has experienced two significant earthquakes: one at L'Aquila, in 2009, and another in 2016, centred in Amatrice. This article will focus on the most recent earthquake, but the L'Aquila event will be used for comparison and extension where appropriate.

Causes

Geologically, the Central Apennines is a complex area. There are three different plate movements occurring simultaneously:

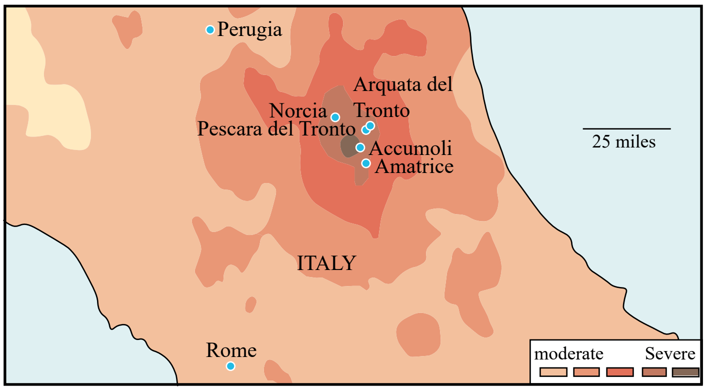
- The Eurasian and Africa plates both move in a north-easterly direction, but the African plate is travelling about twice as fast (21mm per year) and is converging and subducting under the Eurasian plate.
- The Tyrrhenian Basin to the west, in the Mediterranean Sea, is opening at 3mm per year, faster than the major plate movement, and is pulling the Apennines apart, creating extension faults.
- The Adria microplate is rotating anticlockwise and subducting beneath the Eurasian plate and the Apennines from the east. This intraplate movement is responsible for the formation of the Apennines; as the Adria plate has undergone subduction, the sediment has been scraped off the seabed and deposited on the edge of the land mass, forming an accretionary wedge – the Apennine fold mountain belt. They are high mountains, with a zone of faults running along the crests.

Tectonic Hazard Events

On August 24th, 2016, an earthquake measuring M6.2 hit the Central Apennines.

Its epicentre was 10km southeast of Norcia (Figure 1), and followed by many aftershocks in the following week. It was a shallow quake, 4.4km deep, and was felt 135 miles away, in Bologna to the north and Naples to the south. Radar satellites mapped a 20km zone of subsidence between Norcia and Amatrice, along which the crust had moved by up to 23cm. No seismic activity was recorded prior to the earthquake, unlike L'Aquila in 2009, when there was a swarm of foreshocks in the six days leading up to the event.

Figure 1. Location of August 2016 earthquake and its areal effects. Source: USGS



The Apennines experience frequent earthquakes (Figure 2). It is thought the main driver of this frequency is the Tyrrhenian Basin that is opening up at a faster rate than the movement of the Eurasian and African plates (Figure 3). This difference in rates of movement causes stresses within the crust.

The earthquake in August 2016 was due to a shallow fault running NW-SE across the central Apennine region, along which there have been previous events. In 1997, there was a 2-month sequence of earthquakes greater than M5.0, the most destructive being the one at Assisi, where 80,000 homes were destroyed in the region. In April 2009, the town of L'Aquila was the centre of destruction, with 295 deaths and 55,000 made homeless. This was followed by many severe aftershocks greater than M5.0 and significant landslides.

It is thought that the 2016 earthquake is in the seismic gap between the 1997 and 2009 events (Figure 4). Seismic gap theory states that segments of an active fault that have not slipped for a long period of time are the most likely to experience an earthquake, because that is where stresses build up. 20km gaps now exist from Amatrice to Assisi to the NW and to L'Aquila to the SE, as indicated on Figure 4, so it is reasonable to expect that there might be future activity along these segments of the fault. In 1703 there were 3 major earthquakes along the same fault near Norcia, killing 10,000 people. This is highly unusual but did occur, and so it is possible that this may be repeated in the region.

Multiple ruptures and large aftershocks are historically common. The 2016 earthquake has been associated with on-going aftershocks, many of magnitude M5-6 which were again felt widely in the region (October and November 2016) causing psychological stress and yet more damage of historic buildings. A major aftershock occurred on 26th October 2016, M6.1, and on 30th October 2016 yet another earthquake occurred, M6.6, which caused 2 deaths and very widespread damage, mainly of historic buildings. Scientists considered this to be a separate earthquake event.

Figure 2. Timeline of earthquakes in Italy

Date	Magnitude	Epicentre	Deaths
1908	7.2	Messina, Sicily	82,000
1915	7.0	Avezzano, (Central)	32,600
1930	6.3	Irpinia (South)	1,400
1976	6.0	Friuli, (NE)	976
1980	6.5	Eboli, (South)	2735
1990	5.6	Off Sicily	13
1997	6.4	Assisi (Central)	11
2001	5.2	Alto Adige (North)	1
2002	5.9	Campbasso, (South)	30
2009	6.3	L'Aquila (Central)	300
2012	6.1	Modena (North)	26
2016	6.2	Norcia (Central)	298
2016	6.1	Visso (Central)	1
2016	6.6	Arquata del Tronto (Central)	2

Source: USGS

Figure 3. Map showing the tectonic structure of central Italy

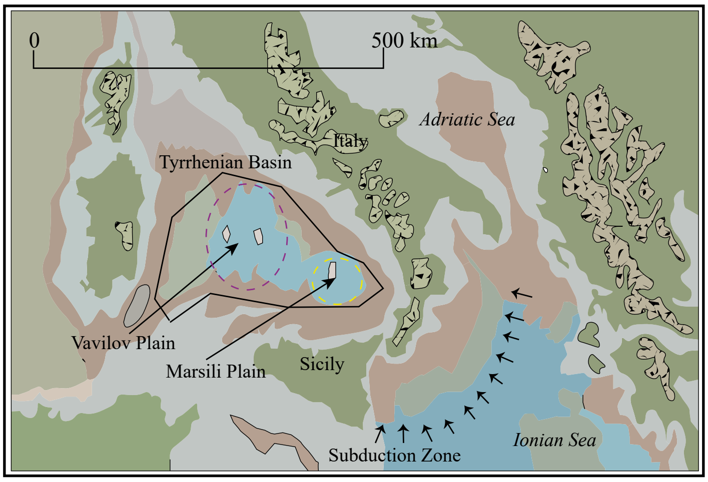
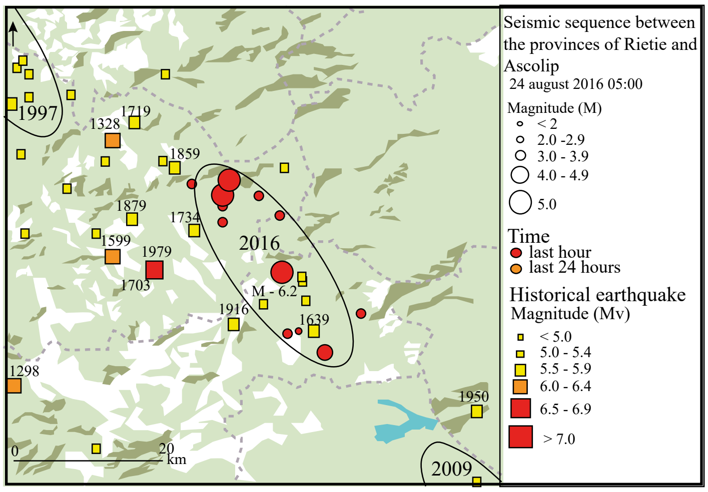


Figure 4. Map showing previous earthquakes in Assisi (1997) and L'Aquila (2009) and Amatrice (2016) along a fault running NW-SE. According to seismic gap theory, future earthquakes might be expected on the fault as indicated. Source: INGV Terramoti



Impact in 2016

Many towns were badly affected, the worst being Amatrice and Accumoli, and smaller villages of Pescara del Tronto and Arquata del Tronto were badly damaged (Figure 1, Figure 5). The death toll of 298 included tourists, as it was the summer season. The earthquake occurred at 03:37 local time, so many were asleep and crushed by collapsing houses; about 4000 were made homeless. Falling masonry blocked roads and hampered the emergency response, especially as the affected villages were ancient hilltop settlements. Nearly 300 historic buildings were destroyed and the earthquake created cracks in the Baths of Caracalla in Rome, prompting the authorities to undergo tests on the Colosseum, which was found to be unaffected.

Figure 5. The destruction of the historic centre of Amatrice

Source: Alessandro Di Meo/AP

Why Was the Impact So Great?

Despite Italy suffering eight major earthquakes in the past 40 years, the degree of destruction has raised questions about the level of preparedness. It is estimated that 70% of Italy's buildings are not constructed to adequate seismic standards. Opportunities to retrofit ancient buildings when they are refurbished, whilst difficult, have been wasted, and many new buildings do not comply with building codes. In Amatrice, a new school, Romolo Crapanica, rebuilt in 2012 and costing €700,000, was reduced to rubble, whilst a 13th century civic tower remained standing. Antiseismic construction laws were introduced in 1973, but the use of concrete beams, rather than wooden ones, is widespread, even though they are less resistant to stress. After L'Aquila in 2009, €1bn was earmarked for upgrading buildings, but very little has been used, thought to be due to bureaucracy in regards to accessing the funds. The Mafia is also suspected of obtaining building permits without the intention of doing the work, in order to maximise their profits.

Response

During the immediate relief effort, survivors and rescue teams used sniffer dogs, bulldozers, and bare hands to find people buried in the rubble. 12 helicopters were used, as road access was impossible in many places. Tent cities were erected and emergency kitchens catered for the homeless. According to the National Civic Protection Agency, 5,000 people, half of them volunteers, responded in the immediate aftermath. Emergency funding of €50m was authorised by the national government, which also cancelled residents' taxes in the worst-hit settlements. Rescue teams asked locals to unlock their Wi-Fi passwords so that home networks could assist with communications. It was argued that the possible breach in security was far outweighed by the gravity of the situation. More than 600 restaurants across Italy put the local dish of pasta amatriciana on the menu and donated €2 per order to the Red Cross.

Rebuilding Resilience

A new national plan to reform Italy's earthquake preparedness plans, called "*Casa Italia"*, is to be introduced following calls for longer term preparedness rather than just emergency planning. A major emphasis will be the issue of applying seismic standards to buildings throughout Italy. It is estimated that €90bn would be necessary to reinforce all Italy's historic buildings over the next 50 years; some argue this is unrealistic but that targeted sites would be possible. 20,000 schools are located in the two highest hazard risk zones throughout the country, as well as nearly 2,000 hospitals and millions of homes. "Safe Schools" has been a key government policy in recent years, with €4bn spent since 2014 on strengthening school buildings. Educational establishments have suffered collapse and deaths in each of the last three major earthquakes.

Construction is key to this disaster. Models run by the United States Geological Survey show that if 10,000 people were subjected to Modified Mercalli Intensity IX (as in Amatrice and Accumoli in 2016) and all factors were constant, 3,000 deaths would occur in Iran, 150 in Italy, and 3 in California.

A special commissioner has been appointed to oversee the recovery in Amatrice and surrounding villages. However, seven years on from the L'Aquila event, the town centre has not been repaired, and temporary housing is still in use. Issues of funding, corruption, illegal construction and bureaucracy have combined to obstruct both the reinforcement of old buildings and the application of seismic codes to new ones. Prosecution of architects and builders who have disregarded building codes has been suggested.

The judicial system was used after the L'Aquila earthquake in 2009. Despite the known difficulties in predicting earthquakes, six scientists and an ex-government official were convicted of involuntary manslaughter, after a year-long trial ending in October 2012, and each was sentenced to six years of imprisonment.

They were judged to have provided "an assessment of the risks that was incomplete, inept, unsuitable, and criminally mistaken", having said in the six days before the earthquake, when there were seismic swarms in the general region (although not at L'Aquila itself), that an event was "unlikely (although not impossible)" and that there was "no danger". It was decided that the foreshocks were typical of seismic activity ahead of a major tectonic event but that the scientists had interpreted them incorrectly as "normal geological phenomena". Two years later, the sentences were quashed under appeal, except for the government official.

Insurance is another way of increasing societal resilience to natural hazards. However, in Italy the uptake of earthquake insurance is extremely low (1%), especially when one considers the high frequency of earthquakes. Italians generally expect the national government to bear the costs of such events.

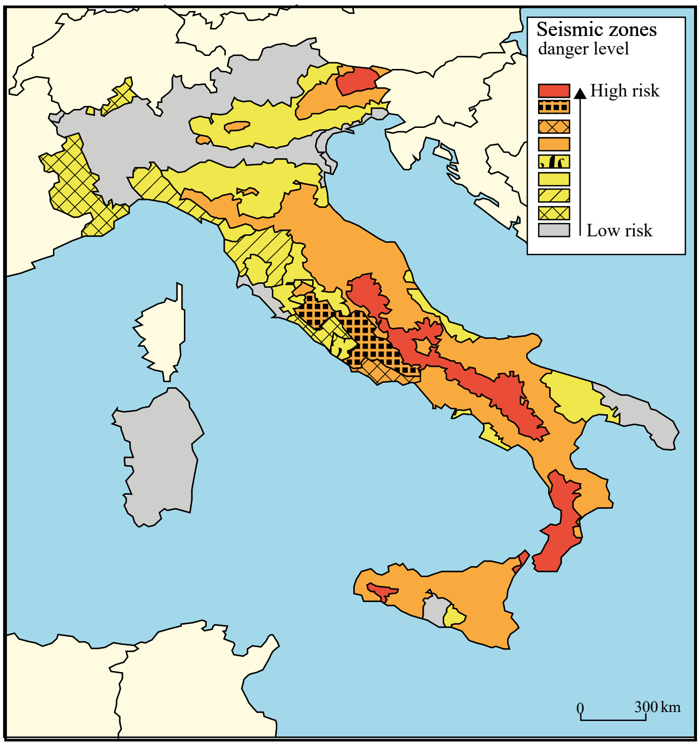
It is estimated that the 2016 event will cost less than L'Aquila in 2009 (€505m), which caused >€10bn of economic damage, representing a significant 0.6% of Italy's GDP. Italy could increase the uptake of insurance by making it compulsory, and national or local governments could provide not-for-profit schemes for private insurance. A further incentive could be that premiums are made tax deductible. Figure 6 shows how some tectonically active countries approach insurance for earthquake risk.

Figure 6. Comparison of insurance uptake in tectonically active countries

Country	Residential earthquake insurance take-up rate %	Basis for cover
Italy	1%	Voluntary
Japan	60%	Voluntary
New Zealand	80-85%	Compulsory, added to domestic insurance policies
Turkey	40%	Compulsory, but no sanctions; incentive is additional value when the property is sold

A detailed national seismic hazard map is available (Figure 7). It is based on past records of earthquakes, the location of active faults, and crustal strain measurements from GPS receivers. It clearly shows the areas needing priority in preventative measures, but scientists who created the map believe that public authorities do not give it enough attention in their planning processes. The 2009 and 2016 events occurred in the highest risk zone.

Figure 7. Map of seismic risk zones. The red central zone has the highest risk of earthquakes



Early warning systems are not deployed in this region, but they would not have been effective in these recent earthquakes. The distances from the epicentre to the settlements was so short that there would not have been time for alarms to reach mobile phones or public sirens. At best, had there been a dense network of gauges, people in Amatrice could have got under a table, but not out of the houses. Also, there had not been a swarm of foreshocks to alert scientists, as had been the case in L'Aquila, and these are rare anyway.

Conclusion

Resilience could be improved by compliance with building codes, as it is estimated that 64% of Italy's population live in areas where buildings are vulnerable to earthquakes. Insurance would be a very effective measure to increase societal resilience, especially as it would reflect the global move towards disaster risk reduction, rather than paying for damage after the event. *Casa Italia* is the latest national preparedness plan and needs to include up-to-date approaches to managing disaster risk. All measures possible need to be taken, as the Central Apennines remains at high risk of destructive earthquakes, due to the shallow faulting pattern along the mountain crests, where historic towns and villages were originally sited for defence purposes. They are a major tourist attraction of Italy, which alone can partly justify the need to spend heavily on strengthening buildings at risk.

References

Seismic gap theory and overview of 2016 earthquake: http://tinyurl.com/h23mgeh

Useful links: http://geography.org.uk/resources/earthquake-and-tsunami-resources/italy-earthquake-2016-geography-resources/

Further Research

Research other associated tectonic hazards within Italy including the active volcanoes of Stromboli and Etna and the semi-dormant volcano of Vesuvius. You should explore how these volcanoes are being managed.

www.rgs.org/ Tectonic case studies pdf

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