



EARTHQUAKE



UNCORRECTED PAGE PROOFS





The Earth series traces the historical significance and cultural history of natural phenomena. Written by experts who are passionate about their subject, titles in the series bring together science, art, literature, mythology, religion and popular culture, exploring and explaining the planet we inhabit in new and exciting ways.

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Earthquake

Andrew Robinson



REAKTION BOOKS





*In memory of my parents, who experienced the
Loma Prieta earthquake in California in 1989*

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1 Earth-shattering Events

Not long after midnight on an ordinary evening in late February 2008, I had an uncanny seismic experience. I had just finished writing a review for the scientific journal *Nature* of an intriguing new book by a Californian seismologist with the attention-grabbing title *Apocalypse: Earthquakes, Archaeology, and the Wrath of God*. While editing my draft, I felt the floor in my fourth-floor flat in London shift almost imperceptibly for a second or two. My partner joked that it must be an earthquake, but I couldn't believe it. In four or five decades I had never knowingly witnessed a British earthquake. Perhaps the vibration had been caused by a London Underground train passing not far away from our early Victorian square. I forgot about it and went to bed.

The following morning, however, the BBC radio news bulletin confirmed that there really had been an earthquake, at 12.56 a.m. The British Geological Survey had monitored the event as having occurred at a depth of 5 kilometres (about 3 miles), with its epicentre in the county of Lincolnshire, around 200 kilometres (125 miles) roughly north of London, and with a potentially destructive magnitude of 5.2. According to the survey's records it had been the biggest earthquake in the United Kingdom since 1984; in other words, for nearly a quarter of a century.

One serious injury was reported: a student in his attic bedroom was hit on the pelvis by a falling chunk of chimney stack. Many houses close to the epicentre suffered damage, chiefly to chimneys, roofs and garden walls. And a lot of people were





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rudely awoken from sleep and became alarmed enough to go into the street; local emergency services and the British Geological Survey were inundated with calls. A resident of nearby Scunthorpe told a national newspaper: 'My whole house shook like it was going to fall over and it felt as if the whole roof was coming off. I thought a tree had been thrown into the roof by a tornado or something.' Another witness, further away from the epicentre to the south, in Northampton, also thought that his house was coming down. He added: 'I knew it was an earthquake straight away. It was as strong as I have ever felt anywhere, and I lived on the west coast of America for four years.' A third person, resident on the nearby east coast, commented that the tremor was 'much stronger' than one he had experienced in Los Angeles.¹

Every year in Britain some 200 minor tremors are recorded by seismographs. A magnitude-4 earthquake occurs every two or three years on average; a magnitude-5 quake every ten years on average. In 1931 there was a quake of magnitude 6.1 – the largest British earthquake measured by seismologists to date. As a rule 90 per cent of these tremors go undetected by the public. Those that are noticed – like the 5.2-magnitude earthquake on 27 February 2008 – are rapidly forgotten. To most people earthquakes and England would appear to have little connection, and British earthquakes seems a topic that offers hardly anything of interest to a writer compared with the almost apocalyptic earthquakes that strike places such as California and Alaska, Chile and Peru, Mexico and the Caribbean islands, North Africa, Portugal and Italy, Turkey and Iran, Pakistan and India, Indonesia, New Zealand, China and Japan, where violent shaking of the earth has devastated towns and cities and killed millions of people in the modern period. (In China alone earthquakes have claimed 13 million lives since records began three millennia ago, of whom 830,000 died in one mega-disaster in 1556.) Yet the facts of the historical record show that such complacency and indifference towards British earthquakes are unwarranted.

An authoritative study of the subject, *A History of British Earthquakes* by a mathematician, Charles Davison, published by Cambridge University Press in 1924 just before the advent of





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modern seismography, lists 1,190 earthquakes that the author was able to authenticate. For the period up to AD 1000 Davison was compelled by lack of evidence to consider a rare, two-volume compilation published in London in 1749 by a Sheffield physician and Fellow of the Royal Society, Dr Thomas Short, entitled *A General Chronological History of the Air, Weather, Seasons, Meteors, etc.* Short noted that he had spent sixteen years collecting his 'scraps of histories', but sadly he elected to provide virtually no details of his sources.² His first report of a British earthquake, dated AD 103, refers to an unnamed 'city' in a western English county, Somersetshire, which was supposedly 'swallowed up, name and all' – a disaster that seems highly improbable, and was dismissed by Davison. A later report by Short, dated 811, states that an earthquake 'destroyed' St Andrews in Scotland ('most of the town and 1,400 people') – another claim dismissed by Davison and others as a tall story.³

But after leaving behind Short's catalogue, Davison's sources become more reliable, that is, from about 1000 onwards, and give examples of some authentic British earthquakes. In 1114, during a violent earthquake in England – which coincided with one in Italy – the unfinished walls of a new Lincolnshire church at Croyland (modern name Crowland) 'gave way, and the south wall was cracked in so many places that the carpenters were obliged to shore it up with timbers till the roof was raised'.⁴ In 1248 the vaulted roof of the celebrated medieval cathedral at Wells in Somerset was thrown down by an earthquake. In 1580, in London, a boy and a girl died during an earthquake under masonry falling from Christ's Church Hospital, St Paul's Cathedral was slightly damaged and the great bell in the Palace of Westminster was set ringing. At Dover part of the white cliffs fell into the English Channel along with a portion of the castle wall. In 1692 a violent shock with its probable focus in Brabant (what is now the Netherlands and Belgium) made people in London 'greatly affrighted', according to a letter written soon after by the diarist John Evelyn, whose son lived in central London. Evelyn himself, then in Surrey, felt only a minor tremor.⁵

During 1750, which became known as the 'year of earth-



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5 Earthquake alarm in London, April 1750, engraving.

quakes', several areas of the country were shaken. In London four shocks occurred in February and March, the fourth of which was centred two or three miles north of London Bridge, lasted for between five and six seconds and caused great stones to fall from the new spire of Westminster Abbey. This was followed by a tremor on 20 March. Londoners became so alarmed by a madman's prediction of a future shock on 7–8 April that thousands of them chose to spend the night out of doors, either in tents in Hyde Park, in their carriages or simply in the open. Some women even had 'earthquake gowns' made to keep them warm while sitting outside on this unique occasion, noted the aristocratic Horace Walpole in an amused letter to a friend on 7 April. Those who could afford it – some members of the nobility and the gentry – left London altogether: 'within these three days 730 coaches have been counted passing Hyde Park Corner, with whole parties removing into the country', reported a sceptical Walpole.⁶ Nothing happened on the predicted day (though in June there was a 'loud report like that of a cannon' at London and Norwich, without any tremor).⁷ But the earthquakes proved a boon to certain clergymen, including the evangelist John Wesley, who prayed from their pulpits that sinful Londoners would repent and avert God's wrath. Moreover,



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56 The Great English Earthquake

TERRIBLE EARTHQUAKE IN ESSEX.

Great Alarm & Damage to Property at Colchester.

LANGENHOE CHURCH DESTROYED

Wyvenhoe, Messes, and other Parishes Wrecked.

Not within living memory has Colchester been thrown into such a state of excitement, consternation, and panic, as it was soon after nine o'clock on Tuesday morning, when the town was visited by a fearful and most appalling earthquake, which will remain in the recollection of those who experienced it to their dying day. Everything was peaceful and quiet as in the evening, so fresh atmospheric change from the last few days, with the exception of a slight elevation of temperature, being experiment to indicate in any way the approach of a variation of this nature, from which England happily has been very free, and has had little reason to anticipate anything of the kind either in trees down by or at this more immediate period. The actual event occurred between a quarter and twenty minutes past nine o'clock, ending without the slightest warning and lasting from five to ten seconds, but in that short period of time, an amount of damage was done to property which it will take weeks to set right, and the more some the destruction is terrible. From one end of the town to the other the ground was convulsed, and if a spectator could have taken a bird's eye view of the Borough, the effect would have been much the same as a sea wave, the ground opening and closing by means of that gigantic process past up beneath the earth's crust. The general impression appears to be that the ground and the houses with it was lifted up, shaken two or three times in a manner that made the stones loose, and the houses to row with fear, and then subsided, accompanied with a kind of shock or jerk, and then all was over. No noise like the rattling sound of articles in the distance, or crash similar to that of a thunderbolt, or the rattling of the building itself, could be heard, nor was there any shaking of the houses, but there was simply a sort of low rattling sound, caused by it was some of the opening and shaking of the houses then anything else. Not a house in the Borough escaped the mighty influence. Windows cracked, beds were set a quiver, pictures dislodged from the walls, vases and ornaments overturned, and in all of damage of a more serious character was done in the space of a few seconds.

6A 'Terrible Earthquake in Essex', the Great English earthquake, 1884.

6B Havoc in Colchester, the Great English earthquake, 1884, magazine illustration.

many Fellows of the Royal Society, most notably John Michell at Cambridge University, were at last provoked to begin research into earthquakes. By the end of 1750 almost 50 articles and letters on the subject had been read before the Royal Society, which were promptly published as an appendix to its *Philosophical Transactions*. Davison notes that the serious study of British earthquakes may be said to date from this time.

Then, at 9.18 a.m. on 22 April 1884, came the so-called Great English earthquake, the most damaging quake of all, which wrecked houses and toppled churches in and around the ancient Roman town of Colchester in the coastal county of Essex while pitching the engine driver of the waiting Colchester to London 9.20 a.m. express train out of his cab onto the station platform. It also rattled nearby London. In the Houses of Parliament, within the Palace of Westminster, puzzled MPs were 'stopped in their tracks, jolted against walls, or felt papers and briefcases jerked from their hands'.⁸ Officials were immediately dispatched to investigate the possibility that there had been a Guy Fawkes-style explosion in the cellars of the palace, perhaps set off by the notorious Dynamiters who were at that time being prosecuted by the police for their anarchist activities. The British earthquake of 1884 lasted for perhaps five sec-



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onds (like that of March 1750) according to a reliable eyewitness near the epicentre, a professional sailor who was no stranger to earthquakes in other lands. Had it lasted a few seconds longer, noted a sober report in a local Essex newspaper four days after the dramatic disturbances, 'there is little doubt that the countryside would have been completely destroyed and the loss of life would have been incalculable'.⁹

England's greatest writer, William Shakespeare, was clearly alive to the reality of local earthquakes in the sixteenth century judging from a number of references to them in his works. In *King Henry IV Part I* Hotspur declares:

Diseased nature oftentimes breaks forth
 In strange eruptions, oft the teeming earth
 Is with a kind of colic pinch'd and vex'd
 By the imprisoning of unruly wind
 Within her womb, which for enlargement striving
 Shakes the old beldam earth, and topples down
 Steeples and moss-grown towers (III, i).

Three significant English earthquakes – in London in 1580, in Canterbury in 1580 and near York in 1581 – are known to have occurred during the early youth of Shakespeare, who was born in 1564. One of them is thought to have been the source of a topical reference in his play *Romeo and Juliet*, when Juliet's nurse remembers an unforgettable day:

'Tis since the earthquake now eleven years,
 And she was wean'd – I shall never forget it –
 Of all the days of the year upon that day (I, iii).

The most likely candidate is the London earthquake of 1580, which caused a real stir, as we know. Some Shakespeare scholars have therefore dated the original composition of *Romeo and Juliet* to 1591, eleven years after the earthquake. Others, however, prefer 1596, the year before the play's first publication.

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7 Earthquake depicted in *The Illustrated Bartsch*, before 1500, woodcut.

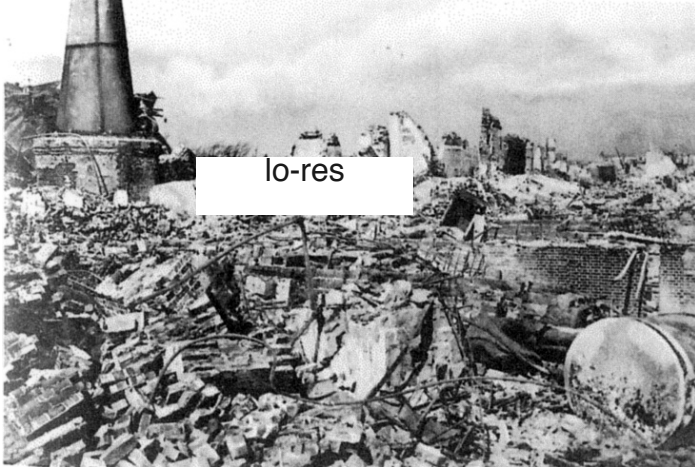


All of this is not to suggest that British earthquakes have any global significance. Indeed, they will hardly rate another mention in this book. But their very existence over many centuries serves to illustrate the truth that no part of the earth is entirely free from the effects of earthquakes – not even stolid Britain.

On the other side of the planet, by contrast, on the Pacific ‘Ring of Fire’, jittery Japan is, of course, an authentic earthquake nation – perhaps the quintessential one, given that most of the country has long been severely affected by shaking and the Japanese have made earthquakes a part of their government and culture. Seismologists have determined that today’s Japan receives nearly 10 per cent of the world’s annual release of seismic energy.

Shortly before lunchtime on 1 September 1923 Japan was struck by its worst-ever earthquake, just as charcoal and gas braziers were cooking the midday meal in a million wooden houses. The capital, Tokyo, its international port Yokohama and the surrounding areas were subjected to between four and five minutes of shaking, followed shortly after by a tsunami – a seismic sea wave – 11 metres (36 feet) in height. Soon multiple small fires

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7 Ruins of the Grand Hotel, Yokohama, 1923, after the Great Kanto earthquake.

started in panicked people's kitchens and, feeding on the congested houses, merged to form terrifying firestorms that burned through the night. By the morning of 3 September at least 140,000 people were dead and two-thirds of Tokyo, four-fifths of Yokohama, were ashes and debris. An area of Tokyo comprising 18 square kilometres (7 square miles) was incinerated (as compared with almost 13 square kilometres of San Francisco after its famous 1906 earthquake, and just 1.7 square kilometres of London in the Great Fire of 1666). Yokohama, with its preponderance of recent stone and brick structures built in imitation of a European city, suffered more from the shaking than fire-ravaged Tokyo. All that remained of Yokohama's Grand Hotel were piles of rubble. Even now, in the small sepia-toned photograph printed in the official report of 1926 of the Great Kanto earthquake introduced by Japan's prince regent, the future Emperor Hirohito, the utterly ruined Grand Hotel is an arresting sight. The photo's caption states baldly: 'No human work can withstand the violence of Nature.'¹⁰

After all great natural disasters the fearful survivors cannot help but look for someone to blame – whether it be mischievous animals and malicious devils, angry gods or incompetent governments and scientists, corrupt builders, foreign agents or sinful individuals.

*Earth-shattering Events*

In India, among the Hindus, the legend was of eight great elephants supporting the earth. When an elephant became weary from time to time, it lowered its head and gave it an earth-shattering shake. In Mongolia lamas imagined instead a gigantic frog carrying the earth on its back. The frog's periodic twitches produced earthquakes. Among the Tzotzil people of southern Mexico the story was of a cosmic jaguar scratching itself against the pillars of the world and causing earthquakes. The inhabitants of an island in Indonesia attributed earthquakes to a demon, which shook with rage when not propitiated by certain sacrifices.

In classical antiquity Poseidon, the Greek god of the sea, was usually considered to be responsible for earthquakes – perhaps not surprisingly, given the destructive power in the Aegean and Mediterranean of earthquake-induced tsunamis. Poseidon was said to cause earthquakes while striking his trident on the ground when he became annoyed. However, some Greek philosophers proposed natural, rather than divine, explanations for earthquakes. Thales, for example, writing around 580 BC, believed that the earth was floating on the oceans and that water movements were responsible for earthquakes. By contrast, Anaximenes, who also lived in the sixth century BC, proposed that rocks falling in the interior of the earth must strike other rocks and produce reverberations. Anaxagoras, during the fifth century BC, regarded fire as the cause of at least some earthquakes. Aristotle, a hundred or so years later, believed in a 'central fire' inside caverns in the earth from which flames, smoke and heat rapidly rose and burst violently through the surface rocks, causing both volcanic eruptions and earthquakes. As the subterranean fires burned away the rocks, the underground caverns would collapse, causing earthquakes. Aristotle even classified earthquakes into types according to whether they shook structures and people in mainly a vertical or a diagonal direction, and whether or not they were associated with escaping vapours. Much later, the Roman philosopher Seneca, inspired in part by an Italian earthquake in AD 63, proposed that the movement of air – rather than smoky vapours – trapped and





7 Poseidon sitting on a shell by Matthys Pool, 1725, engraving.

compressed within the earth, was responsible for both violent storms and destructive rock movements.

In Catholic Europe the wrath of God was generally seen as the cause of earthquakes. Thus, after the shaking down and incineration of much of Lisbon in 1755, the Inquisition responded by charging some of the survivors with heresy and roasting them in the fires of the *auto-da-fé* – a response that helped to provoke the French rationalist Voltaire into writing his

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celebrated satire, *Candide*. In Spanish-ruled colonial South America sins against morality were invoked. Heinrich von Kleist's 1807 German novella, *Das Erdbeben in Chili* (*The Earthquake in Chile*) – based on a real earthquake in Santiago in 1647, according to its opening sentence, but apparently motivated by the great 1755 disaster at Lisbon – imagines the residents of a devastated Santiago blaming the earthquake on the behaviour of two adulterous lovers; the people proceed to club them to death. In North America the Yurok tribe interpreted the San Francisco earthquake of 1906 as punishment for white men who had stolen tribal artefacts and displayed them in museums in San Francisco and nearby Berkeley. Even in the mid-twentieth century Mahatma Gandhi could say, after a great earthquake in northern India in 1934: 'Visitations like droughts, floods, earthquakes and the like, though they seem to have only physical origins are, for me, somehow connected with men's morals.'¹¹



7 Earthquake by Jean Cousin the Elder, 16th century, drawing.

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In the Japanese tradition the most common explanation for earthquakes involved a *namazu*, a giant catfish living in the mud beneath the earth. The creature was normally restrained by a god who protected Japan from earthquakes by keeping a mighty rock on the *namazu's* head. The supposed rock can be seen at Kashima, a place about 100 kilometres (60 miles) from Tokyo that has been comparatively free of earthquakes. However, the Kashima god would occasionally have to leave his post in order to confer with other gods. At such times the *namazu* was free to twitch its barbels, writhe around and generally play pranks – with disastrous results for human beings. The mythology is brilliantly and humorously depicted in coloured woodblock prints, known as *namazu-e*, made after an earthquake near Edo (modern Tokyo) in 1855. In one print, the restless catfish is seen being attacked by every inhabitant of Edo's red-light district except for the carpenters and other artisans, who inevitably do well out of earthquakes. Today images of catfish appear in emergency earthquake preparedness activities in Japan, such as the Earthquake Early Warning logo of the Japan Meteorological Agency.

By the time of the Great Kanto earthquake in 1923, however, the rapid spread of Western ideas and science in Japan meant that few Japanese believed in the tradition; indeed, *namazu-e* sold poorly in 1923, as compared with the outpouring of images in 1855. Instead of supernatural catfish, many residents of Tokyo pointed an accusing finger at Tokyo's immigrant Korean labouring community, a group generally despised by the native Japanese as a result of Japan's annexation of Korea in 1910. Following the fires a rumour swept through the darkened city that Korean saboteurs had started the conflagration and had also poisoned the wells; they were even said (by Japanese-owned newspapers) to be plotting the assassination of the Japanese imperial family. In the days that followed, between 6,000 and 10,000 Koreans were lynched by Japanese vigilantes, some of them with the connivance of nationalistic members of the military and police; the true number of massacred Koreans is unlikely to be established, in the absence of any official inquiry since 1923.

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Japan's most famous film director, Akira Kurosawa – legendary for his dramatization of the extremes of human behaviour in such movies as *Rashomon*, *Seven Samurai* and *Throne of Blood* (a version of *Macbeth*) – was a schoolboy of thirteen at the time of the earthquake, living in a hilly suburb of Tokyo. His family house was badly damaged and its electricity supply knocked out along with the power in the rest of the city, but he and his family were lucky to escape physically unscathed. In his fascinating and frank autobiography, written six decades later, Kurosawa devotes three sections of the book – ‘September 1, 1923’, ‘Darkness and humanity’ and ‘A horrifying excursion’ – to the Great Kanto earthquake. He observes: ‘Through it I learnt not only of the extraordinary powers of nature, but of extraordinary things that lie in human hearts.’¹²

8 *Namazu* (catfish) is attacked by inhabitants of Edo (Tokyo) following the Ansei earthquake, 1855, woodblock print.

Kurosawa's military-minded father – something of a samurai to his son – was mistaken for a foreigner while going in search of missing relatives in a burned-out area because of his full beard. He was surrounded by a mob wielding clubs, who



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dispersed only when he thundered 'Idiots!' at them in Japanese. At home the young Akira was told to keep watch at night with a wooden sword in his hand over a drainage pipe, narrow enough for a crawling cat, in case Koreans were able to sneak through it. He was warned, too, not to drink the water from a neighbourhood well because its surrounding wall carried white chalk marks written in a strange Korean code. But the grimly absurd truth was that Akira himself had been responsible for these meaningless scribbles.

When the holocaust in central Tokyo had died down, Kurosawa recalls how his elder brother invited him to take a look at the ruins:

I set out to accompany my brother with the kind of cheerfulness you feel on a school excursion. By the time I realized how horrifying this excursion would be and tried to shrink back from it, it was already too late. My brother ignored my hesitation and dragged me along . . .

At first we saw only an occasional burned body, but as we drew closer to the downtown area, the numbers increased. But my brother took me by the hand and walked on with determination. The burned landscape for as far as the eye could see had a brownish red colour . . . Amid this expanse of nauseating redness lay every kind of corpse imaginable. I saw corpses charred black, half-burned corpses, corpses in gutters, corpses floating in rivers, corpses piled up on bridges, corpses blocking off a whole street at an intersection, and every manner of death possible to human beings displayed by corpses. When I involuntarily looked away, my brother scolded me, 'Akira, look carefully now.'

. . . In some places the piles of corpses formed little mountains. On top of one of these mountains sat a blackened body in the lotus position of Zen meditation. This corpse looked exactly like a Buddhist statue. My brother and I stared at it for a long time, standing stock still. Then my brother, as if talking to himself, softly said, 'Magnificent, isn't it?' I felt the same way . . .

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The night we returned from the horrifying excursion I was fully prepared to be unable to sleep, or to have terrible nightmares if I did. But no sooner had I laid my head on the pillow than it was morning. I had slept like a log, and I couldn't remember anything frightening from my dreams. This seemed so strange to me that I asked my brother how it could have come about. 'If you shut your eyes to a frightening sight, you end up being frightened. If you look at everything straight on, there is nothing to be afraid of.' Looking back on the excursion now, I realize that it must have been horrifying for my brother too. It had been an expedition to conquer fear.¹³

Tokyo was rebuilt within about seven years, essentially where it had been before. Today, vastly expanded and more prosperous, Tokyo is considered by the Japanese government to be at high risk of suffering another destructive earthquake, given that it was struck in 1855 and 1923 but has escaped severe damage since then. In 1995 a totally unanticipated earthquake 500 kilometres (311 miles) to the west of the capital, which destroyed parts of the port of Kobe and killed more than 6,400 people, provided some idea of the likely future chaos in metropolitan Tokyo – not to speak of the psychological cost to the Japanese, as suggested by the short stories in novelist Haruki Murakami's collection *after the quake*. Murakami's first story opens with a married woman in Tokyo glued to a television set for five whole days, 'staring at crumbled banks and hospitals, whole blocks of stores in flames, severed rail lines and expressways' in quake-struck Kobe. This nihilistic media exposure drives the woman to divorce her husband, abandoning him with just a note on the kitchen table saying that 'living with you is like living with a chunk of air'.¹⁴ When her former husband later tries to have sex with a woman, he gives up, because he cannot forget the silent images of 'highways, flames, smoke, piles of rubble, cracks in streets' running through his mind like a slideshow.¹⁵

Around the world, more than 60 large cities – in every continent except Australia – are at risk from earthquakes on the basis of their seismic history. They include such conurbations as



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Beijing, Cairo, Calcutta, Delhi, Istanbul, Jakarta, Lima, Los Angeles, Mexico City, the San Francisco Bay Area, Seoul, Shanghai, Singapore, Tehran and, of course, Tokyo and Yokohama. Although European cities as a whole have been comparatively less affected, highly destructive earthquakes have struck Athens, Bucharest, Lisbon, Madrid, Messina, Milan, Naples, Rome, Turin and many other Italian towns and cities during the past three centuries.

In the central Italian city of L'Aquila, for example, a relatively small – magnitude-6.3 – earthquake killed 309 people and caused much destruction in 2009. L'Aquila had been largely destroyed by earthquakes before, in 1461 and 1703. The disaster of 2009 would quickly have been forgotten outside Italy were it not for its bizarre aftershock. For the first time in the world the authorities of a city struck by an earthquake brought a charge of manslaughter against scientific experts on earthquake hazards. L'Aquila's public prosecutor accused six government scientists

11 Earthquake destruction, L'Aquila, Italy, 2009.

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and one government official of underestimating the seismic risk, thereby encouraging residents to stay in their homes and expose themselves to unnecessary danger. The international seismological community was shocked and outraged. Although seismologists can predict where to expect most earthquakes, with the help of plate tectonic theory, they know that they are still far from being able to predict the precise locations and timings of major shocks, despite periodic claims to the contrary.

Earthquake disasters have at least one benefit: they educate seismologists. The naturalist Charles Darwin, who was also a significant geologist, wrote in his classic travel journal *The Voyage of the Beagle* that his experience of an earthquake in the city of Concepción on the coast of Chile was perhaps the single most interesting event of his entire five-year expedition around the world between 1831 and 1836. Just after the earthquake occurred in February 1835, an excited Darwin recorded:

It is a bitter and humiliating thing to see works, which have cost men so much time and labour, overthrown in one minute; yet compassion for the inhabitants is almost instantly forgotten, from the interest excited in finding that state of things produced in a moment of time, which one is accustomed to attribute to the succession of ages.¹⁶

Yet, for all the amazing advances in seismological science and earthquake-resistant engineering during the second half of the twentieth century, and the improved disaster preparedness of governments and international aid agencies, earthquakes continue to cause immense loss of life, property damage and infrastructural damage in the early twenty-first century. The Indian Ocean earthquake of 2004 (also known as the Sumatra-Andaman earthquake), with a magnitude of 9.1–9.3, created a tsunami that killed more than 230,000 people in fourteen countries, the worst affected being Indonesia, Sri Lanka, India and Thailand. In 2010 the magnitude-7.0 earthquake that struck Haiti very close to the capital, Port-au-Prince, wrecked much of the city and took many tens of thousands of lives, according



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to reliable estimates made in 2011 (more than 300,000 lives, according to the Haitian government). A pair of earthquakes near Christchurch, in New Zealand, six months apart in 2010 and 2011, took far fewer lives (181 fatalities) than the Indian Ocean and Haiti quakes, as is typical of earthquakes in developed countries. But instead they cost the government, insurance companies, businesses and individual householders many billions in U.S. dollars. The second New Zealand earthquake, though only of magnitude 6.3, caused such widespread weakening of the soil beneath Christchurch through the shaking process known as liquefaction that parts of the city – including more than 5,000 homes – were declared uneconomical to rebuild. The damage made this comparatively small earthquake New Zealand's most costly natural disaster by far, and the third costliest earthquake disaster ever, after the magnitude-6.7 Northridge earthquake

11 Earthquake damage, Jacmel, Haiti, 2010.



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near Los Angeles in 1994 and the magnitude-9.0 Tohoku-Oki earthquake in 2011.

No one will ever forget the crisis provoked by the second of these latter two disasters (also known as the Great East Japan earthquake), which was described by the then Japanese prime minister as the 'toughest and most difficult crisis for the country' since the Second World War.¹⁷ The epicentre was under the Pacific Ocean, 70 kilometres (43 miles) off the east coast of Japan near the Japan Trench, and the predictable result was yet another Japanese tsunami, which in this instance reached a staggering maximum height of 39 metres (128 feet). The waves not only drowned well over 20,000 people but overwhelmed the Fukushima Daiichi nuclear power plant. The damage to its operating systems precipitated a core meltdown, the most serious nuclear accident since the Chernobyl disaster in 1986, and a re-

11 Earthquake damage, Christchurch, New Zealand, 2010.



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11 Tsunami destruction of Miyako, Japan, following the Tohoku-Oki earthquake of 2011.

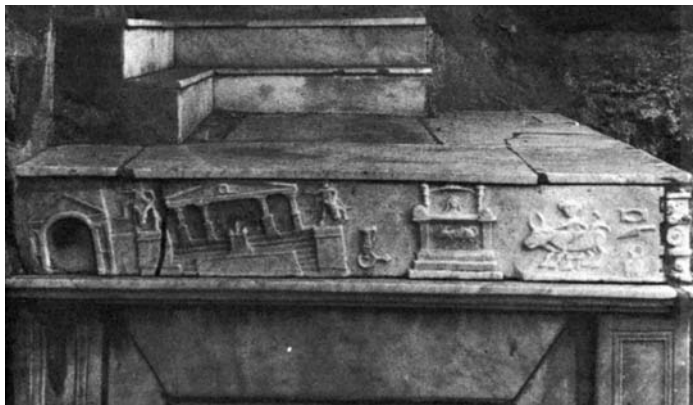
thinking of the dangers of nuclear power both in Japan and worldwide. This led the German government to announce that it would close its nuclear power stations by 2022.

The power of earthquakes, coupled with the fires that follow them, is certainly awesome. Pompeii was so damaged by an earthquake in AD 62 or 63 that the Roman emperor Nero, after a visit, recommended the city be abandoned. Antioch, a trading and pleasure city on the shores of Asia Minor, was devastated four times by earthquakes in AD 115, 458, 526 and 528. In central America Antigua, the capital of Guatemala, was ruined four times from 1586 in less than 300 years; Managua, the capital of Nicaragua, ten times in fewer than two centuries. Yet all these cities – as well as ruined Lisbon, San Francisco and Tokyo, of course – were rebuilt on the same site as before, and flourished, with the exception of Pompeii, which had the misfortune to be buried by the volcanic eruption of Vesuvius in AD 79. The only major city in the historical record to have been more or less abandoned after an earthquake and tsunami is Port Royal in Jamaica, much of which literally slid under the sea in 1692.

How influential in history have earthquakes really been, for all their horrors? Certainly less influential than Darwin imagined in Chile in 1835 after examining the ruins of Concepción, when he darkly contemplated what would happen to England in

Earth-shattering Events

12 Relief from a house in Pompeii depicting destruction by the earthquake of AD 62 or 63.



the event of a major earthquake, and noted in his journal: 'Earthquakes alone are sufficient to destroy the prosperity of any country.'¹⁸ That said, a fairly convincing case can be made for a long-term decline in Portugal's power and influence as a consequence of the destruction of its capital, Lisbon, in 1755. Undoubtedly, if we accept the account given by Latin America's liberator, Simón Bolívar, it was an earthquake in Venezuela in 1812 that directly influenced Bolívar's freeing of Bolivia, Colombia, Ecuador, Peru and Venezuela from Spanish colonial

13 Ruins of the cathedral at Concepción, Chile, following the earthquake in 1835, engraving.



EARTHQUAKE



12 (204) Earthquake destruction, Port Royal, Jamaica, 1692, engraving.

rule in the 1820s. For this earthquake precipitated the collapse of Bolívar's first republican government of Venezuela under Spanish attack, forcing him into exile, where he became the leader of a much wider independence movement than the one he had led in Venezuela. In Japan the massive cost of rebuilding Tokyo in the 1920s, closely followed by the worldwide economic depression of the 1930s, produced an economic stress that led to the militarization of Japanese society and eventually to Japan's entry into the Second World War. In Mexico the ruling party's failure to deal with the aftermath of the Mexico City earthquake

Earth-shattering Events

12 Ruins of City Hall, San Francisco, following the earthquake and fire in 1906.



in 1985 distinctly weakened the sclerotic hold on power it had had since the 1920s. And in Sri Lanka the Indian Ocean earthquake of 2004 helped to solidify the grip of a strongly nationalist government dominated by the majority Sinhalese, which soon took the decision to annihilate the minority separatist movement led by the Tamil Tigers.

At a much earlier period in history, it is possible, though unproven, that earthquakes played a greater role in the decline of cities and civilizations. It is difficult to be sure from the available record. The first reliable reports of earthquakes begin only in 780 BC in China, in 464 BC in Greece and in AD 416 in Japan, although there is a report in the ancient Chinese *Bamboo Annals* of the shaking of Taishan mountain in Shandong province dated as early as 1831 BC. Very likely it was an earthquake that destroyed the biblical cities of Sodom and Gomorrah, judging from the description of their fate in the book of Genesis; there is no certainty, since the cities' archaeological sites have yet to be discovered. Earthquakes are also strong candidates to explain other events of the Bible, such as the collapse of the walls of Jericho and the parting of the Red Sea. They may have been a factor in the catastrophic end of the Bronze Age civilizations in

overleaf:

13 (215) Jan Brueghel the Elder, *Sodom and Gomorrah*, 17th century, painting.



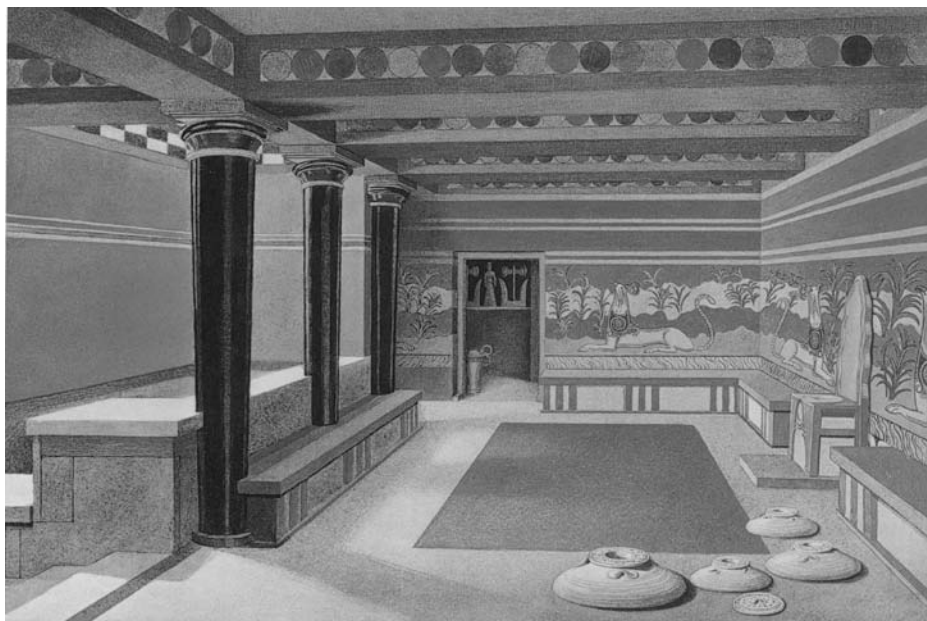


EARTHQUAKE

Turkey, Greece and Crete during a period of around 50 years in the late second millennium BC: that is, the fall of Troy, Mycenae, Knossos and other cities, which left behind substantial archaeological sites. There is also tantalizing evidence for a seismic role in the fall of Armageddon (Megiddo) in Israel, Petra in Jordan and Teotihuacan in Mexico.

However, archaeologists are divided on the importance of earthquakes in the development of civilization. Most present-day archaeologists claim that earthquakes have had little to do with historical demises. They prefer to attribute the collapse of civilizations to human agency: war, invasion, social oppression, environmental abuse and so on. The conventional explanation of the Bronze Age collapse involves maritime invasion by the mysterious Sea Peoples, whose identities have long eluded scholars. 'When a city is destroyed for no apparent reason, archaeologists are far more comfortable ascribing the destruction to the vagaries of an unknown enemy than to the whims of nature', writes the geophysicist Amos Nur in *Apocalypse: Earthquakes, Archaeology, and the Wrath of God*.¹⁹ There were notable exceptions:

13 Throne Room, palace of Knossos, Crete, as recreated by the archaeologist Arthur Evans.



Earth-shattering Events

14 'Decapitated' victim of an earthquake in Jericho, c. 1400 BC. In fact the skeleton was decapitated not by the earthquake but by subsequent fault movement, indicated by the crack.



some academics during the first half of the twentieth century were sympathetic to the idea that earthquakes could crush civilizations. These included Arthur Evans, the first excavator of Knossos, Carl Blegen, who excavated Troy, and Claude Schaeffer, the author of a controversial book on the subject published in 1948. But the majority of academics have always been sceptical. For instance, Robert Drews took pains to quash any earthquake explanation in *The End of the Bronze Age: Changes in Warfare and the Catastrophe ca. 1200 BC*, and Jared Diamond made no mention of earthquakes or volcanic eruptions in *Collapse: How Societies Choose to Fail or Succeed*. If earthquakes really have had so great an influence, the sceptics ask, then where is the hard evidence?

This is what Nur attempts to provide in *Apocalypse*. Drawing upon the evidence from archaeological sites, especially in his native Israel, Nur demonstrates how earthquakes may be detected in the archaeological record by analysing geological formations, faults, structural movement, human remains, the collapse of pillars and walls, and inscriptions. In Jericho, for example, he notes that its excavators found grain under the fallen walls of the city, along with the skeletons of two people killed by the walls' collapse. Had the city simply been conquered by an enemy, without the prior collapse of its walls due to an earth-

EARTHQUAKE



14 (200) Part of the Apocalypse cycle painted on the walls of the medieval church of the Virgin Mary, Karlštejn Castle, Czech Republic, depicting an earthquake

quake, the valuable grain would surely have been seized by the invaders. In Mycenae, he notes that the immense stone blocks of the city's outer wall are built on top of a fault scarp, which must have been created by a major earthquake. By superimposing upon a map of the Bronze Age sites in the eastern Mediterranean that were destroyed between 1225 and 1175 BC a second map of the maximum intensity of seismic ground motion between AD 1900 and 1980, which overlaps remarkably with the first map, Nur postulates that strong seismic ground motion in ancient times, too, may have helped to destroy these Bronze Age cultures. While none of his evidence is conclusive, it is more than merely suggestive. In the ancient world, as in the modern, such earth-shattering events of nature were surely – at least sometimes – influential in changing the course of human history.