INTRODUCTION

EARTHQUAKES AND HISTORY

The Colosseum in Rome. About half of its external wall was destroyed by an earthquake, probably in 1349.

California, with its famous San Andreas fault, used to be 'America's earthquake capital'.[1] But recently it has been overtaken by Oklahoma, noted an alarmed editor-in-chief of *Science*, herself a geophysicist and former director of the US Geological Survey (USGS), in 2015.

Before 2000, earthquakes in Oklahoma – even small ones – were uncommon events; indeed the state had long been reputed for its geological stability and absence of major faults. By 2008, though, Oklahoma was experiencing every year an average of one to two earthquakes of magnitude 3.0 or greater, that is, large enough to be felt. (For comparison, the collapse of the Twin Towers in New York in 2001 registered earthquakes of magnitude 2.1 and 2.3.) In 2009, however, there were twenty such earthquakes; in 2010, forty-two of them. The following year, an earthquake of magnitude 5.6 injured two people in the town of Prague, Oklahoma, and destroyed at least sixteen houses plus a turret on a historic university building in nearby Shawnee. During 2014, the number of earthquakes of magnitude 3.0 or greater rose to 585, nearly triple the rate of California and equivalent to more than a century's worth of normal Oklahoman earthquakes. A quake of magnitude 4.2 shook the town of Cushing, a major trading hub for crude oil known as the Pipeline Crossroads of the World, where 54 million barrels were stored underground. Clearly, something unprecedented and potentially dangerous was going on beneath the state. Was nature preparing for an Oklahoman 'Big One'?

The vast majority of scientists were soon convinced that the Oklahoman earthquakes were not natural, like earthquakes in California, but induced – in other words, man-made.

Geologists and seismologists knew that in the early 1960s a series of earthquakes had occurred near Denver in Colorado, where hitherto the natural seismicity had always been low. Between April 1962 and September 1963 seismographic stations near Denver registered more than 700 epicentres with magnitudes of up to 4.3. Then there was a sharp decline in seismicity during 1964, followed by another series of quakes during 1965. It turned out that the US Army was injecting contaminated water from weapons production at its Rocky Mountain arsenal northeast of Denver

into a deep well, bored to a depth of about 3,660 metres (12,000 feet). Injection of the water began in March 1962 and ceased in September 1963 for a year. It resumed in September 1964 and finally ceased in September 1965. Alarmed residents of Denver succeeded in stopping the army's method of disposal and halting the earthquakes.

With the knowledge from this unplanned experiment in mind, in 1969 the USGS designed an experiment at a disused oil field in Rangely, western Colorado. Using existing oil wells, water was injected into a well or pumped out and the pore pressure of the crustal rock (that is, the pressure of the fluid absorbed by the rock) was measured. At the same time an array of seismographs, specially installed in the area, monitored seismicity. There turned out to be an excellent correlation between higher fluid pore pressure and increased seismicity.

The process of injecting fluid into boreholes drilled by the oil and gas industry is now familiar to the public as 'fracking', that is, hydraulic fracturing of shale rock by pumping water, mixed with chemicals and sand, into a shale formation so as to force out trapped natural gas.

Fracking has been demonstrated to cause micro-earthquakes (too small to be felt) and a few felt earthquakes. In Oklahoma, however, fracking is definitely *not* the culprit. Instead, the cause of the earthquakes is the 'dewatering' of oil from wells abandoned as uneconomical in the 1990s but subsequently restarted with the rising price of oil. The problem is that for each barrel of dewatered oil, these wells produce an average of about ten barrels of salt water, that is, 1,600 litres (350 gallons). This large volume of wastewater is being disposed of by injecting it back deep into the ground, where it enters largely unknown geological faults and frequently induces earthquakes. The deeper the injection, the more likely the water will trigger earthquakes. Similar problems have been reported from other states with wastewater-disposal wells: Arkansas, Colorado, Kansas, Ohio and Texas. Outside the US, oil and gas producers in Canada, China and the United Kingdom have also reported such induced seismicity, along with earthquakes induced by geothermal activities in Germany, Switzerland and elsewhere. 'To a large extent, the increasing rate of earthquakes in the mid-continent is due to fluid-injection activities used in modern energy

production', declared twelve scientists – including one from the Oklahoma Geological Survey (OGS) – in a joint paper published in *Science* in 2015.[2] At the same time, a concerned geology professor at Oklahoma State University told the *New Yorker* magazine: 'As scientists, we *knew* the Dust Bowl was going to happen; it wasn't a surprise. It could have been prevented, but scientists failed to effectively communicate what they knew to the people. I don't want that to happen again.'[3] In 2015, the USGS for the first time included induced seismicity in its seismic hazard maps, covering Oklahoma and surrounding states.

Despite this growing scientific consensus, the drilling of disposal wells remained practically unregulated in Oklahoma. No well was denied a permit by the Oklahoma Corporation Commission on grounds of seismicity, nor was injection of the more than 4,600 existing wells curtailed or shut down, unlike in other US states. When the Oklahoma state legislature officially examined the earthquake problem in 2014 and took evidence from local scientists, its report ignored their evidence for induced seismicity, along with copious published scientific evidence from other oil-producing regions, and preferred to cite a local legislator's speculation that the seismicity might be caused by the state's drought. Even the OGS, in its official statements, did not accept that there was sufficient evidence to link the earthquakes to disposal wells, and claimed that the interpretation that best fitted the data for seismicity and fluid injection was 'natural causes'.[4] Only in 2015 did the overwhelming scientific evidence at last compel the state government to introduce some restrictions on the depth and injection rate of disposal wells located within 10 kilometres (6 miles) of the sites of earthquake swarms or quakes of magnitude 4.0 or greater.

Such wilful blindness to science unquestionably has much to do with the power and influence of the oil and gas industry in Oklahoma, which is said to provide one in five of the state's jobs, directly or indirectly, not to speak of its rags-to-riches mythology of 'gushers' discovered by 'wildcatters' going back more than a century. When homes were destroyed by the Prague earthquake in 2011, some of the home-owners refused to speak up, out of deference to the town's well-respected local energy company.

Not only is the oil and gas industry vital to the state's economy, it also funds much of its education, sport and culture, for example the University of Oklahoma, which houses the OGS in the basement of its fifteen-storey earth sciences building. The rest of this building has statues, and a 'well-manicured' garden nearby, dedicated to the achievement of the 'wildcatters' of the oil and gas industry, as noted by a visiting reporter from the science journal *Nature*.[5] At a private meeting in the university in 2013, its president, together with a billionaire oil man, Harold Hamm – the thirteenth child of an Oklahoman sharecropper, whose company had donated more than $30 million to the university – personally pressurized the state seismologist at the OGS not to give public support to a scientific link between the earthquakes and the industry. Hamm's view, as stated in 2014 after a US congressional hearing, is that the earthquakes are 'certainly not related to oil and gas activity'.[6]

Yet, there is more to this story than a clash between science, business and government, of a kind familiar from the current rancorous US debate over climate change. Oklahoma's geology has created both wealth, in the form of oil and gas, and hazard, in the form of induced earthquakes. Many Oklahomans, whatever their level of income, appear to consider this opportunity for economic prosperity worth the seismic risk.

Their contemporary Faustian bargain with earthquakes – in this case man-made quakes – is one small episode in the long and fascinating history of man's relationship with seismicity. 'People don't like earthquakes, and yet, over and over again, people choose to live in areas susceptible to earthquakes', note two well-known US seismologists, Susan Hough and Roger Bilham, in their historical survey, *After the Earth Quakes*.[7] For the ancient Greeks, Romans, Hebrews and Persians, the Chinese and the Japanese, the Maya and the Incas, and many other peoples, earthquakes were an accepted part of life. From antiquity until the present day, on every continent, civilizations have deliberately accepted the risk of periodic seismic destruction.

* * *

In the mid-19th century, as the study of earthquakes was slowly becoming a science, Charles Darwin, the great English naturalist who originally made his name as a geologist, experienced a severe earthquake on the coast of Chile while he was circumnavigating the planet in His Majesty's ship *Beagle*. In his classic travel diary, generally known as *The Voyage of the Beagle*, Darwin ranked the earthquake and its impact as the most 'deeply interesting' sight of his entire five-year journey.

For Darwin, born and brought up in geologically stable England, this was his first personal encounter with the earth's instability. As he beheld the newly devastated Chilean city of Concepción in 1835, Darwin brooded pessimistically that:

> Earthquakes alone are sufficient to destroy the prosperity of any country. If, for instance, beneath England, the now inert subterranean forces should exert those powers which most assuredly in former geological ages they have exerted, how completely would the entire condition of the country be changed! What would become of the lofty houses, thickly packed cities, great manufacturies, the beautiful public and private edifices? If the new period of disturbance were first to commence by some great earthquake in the dead of night, how terrific would be the carnage! England would at once be bankrupt; all papers, records, and accounts would from that moment be lost. Government being unable to collect the taxes, and failing to maintain its authority, the hand of violence and rapine would go uncontrolled. In every large town famine would be proclaimed, pestilence and death following in its train.[8]

Thankfully Britain has never been put through Darwin's imagined seismic ordeal. Not that even Britain – including its capital London – has been earthquake-free: as recently as 2008, a magnitude-5.2 earthquake caused damage to chimney-stacks, roofs and garden walls, and one serious injury, as reported in the national press. Over the centuries, there have been dozens of British earthquakes, catalogued in Charles Davison's *A History of British Earthquakes*.

One in 1248 threw down the vaulted ceiling of Wells Cathedral. Another in 1580 caused part of the white cliffs at Dover to fall into the English

Channel, killed two children in London, rang the great bell in the Palace of Westminster, and is thought to have influenced William Shakespeare's 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.[9]

The worst one, in 1884, wrecked houses and toppled churches in and around the ancient Roman town of Colchester, while pitching the engine driver of a waiting express train to London out of his cab onto the station platform. It rattled London, too. 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'.[10] Officials were immediately despatched to the cellars of the palace to investigate the possibility that there had been a Guy Fawkes-style explosion, perhaps set off by the notorious Dynamiters who were at that time being prosecuted by the police for their Irish nationalist activities. Fortunately, the shaking lasted for a mere five seconds, with an estimated magnitude of 4.6.

But the most historically significant British earthquakes were undoubtedly those of 1750, the so-called 'Year of Earthquakes', which struck both London and elsewhere in the country. Although they induced the usual panic in the public and righteousness among religious preachers, they also marked a new beginning: the objective study of earthquakes, as reported and analysed at length by the fellows of the Royal Society, then probably Europe's leading scientific organization. Strange to say, earthquake science started in Britain in 1750. These earthquakes therefore, despite their limited damage, deserve a chapter in this book of their own (see Chapter 2).

Of course, no British earthquake has come close to the magnitude of the earthquakes that strike continental European countries, notably Greece, Italy, Portugal and Rumania, and, further afield, Algeria, the Caribbean islands, Chile, China, Colombia, India, Indonesia, Iran, Israel, Japan, Mexico, Morocco, Nepal, New Zealand, Pakistan, Peru, Russia, Taiwan,

Turkey and of course the United States. Not only on its Pacific west coast (around San Francisco and Los Angeles), and in Alaska, but also on its Atlantic east coast (around Boston and Charleston) and even in mid-continent: Missouri experienced an earthquake so powerful that it briefly reversed the course of the Mississippi River in 1812.

In Chile, Concepción has been struck some ten times since its founding in 1550, most recently in 2010 by a magnitude-8.8 earthquake, the sixth largest ever to be recorded by a seismograph. Since the earthquake magnitude scale is not linear, but rather logarithmic, the energy of a high-magnitude earthquake is far greater than one might expect from its magnitude number. Thus, the energy released by a magnitude-8.0 earthquake is about 32 times more than one of magnitude 7.0, and 32 squared (approximately 1,000) times more than one of magnitude 6.0. The most powerful earthquake ever recorded – of magnitude 9.5 in Chile in 1960 – released more than 20,000 times the energy of the atomic bomb dropped on Hiroshima in 1945, and about a quarter of the entire seismic energy release of the planet since the beginning of the 20th century. Rupturing 1,000 kilometres (650 miles) of fault running down Chile's coastline, the 1960 earthquake was so powerful that 'it wobbled the planet' – and also set seismologists thinking about how to devise a universally applicable magnitude scale (used throughout this book), to replace the 'Richter' magnitude scale devised in the 1930s by seismologist Charles Richter for measuring moderate earthquakes in southern California with a specific, outdated seismograph.[11] Western South America, measured solely by the magnitude of its earthquakes and their energy release, rates as 'the most seismically active region in the world'.[12]

Was Darwin correct about the economic fragility of earthquake-prone regions? Clearly not, when we consider the long periods of prosperity in many of the above-listed countries. At the present time, the United States has the world's largest economy, China the second, Japan the third. China and Japan are among the world's most seismically active countries, however seismicity is measured: whether according to contemporary seismographic monitoring, the historical earthquake record or the number of earthquake fatalities. Some 22 per cent of the world's earthquakes of magnitude 6.0 or greater occur in Japan.

On this evidence, we might even argue that destructive earthquakes, for all their horrors, can enhance economic growth over the longer term. 'Earthquakes create a lot of business', remarked the so-called 'father of seismology', John Milne, just over a century ago.[13]

Certainly economic growth resulted from the destruction of San Francisco by an earthquake and fire in 1906 (see Chapter 6). Following a period of reconstruction, San Francisco went on to flourish and in the 1950s give birth to the high-tech industrial area on the San Andreas fault southeast of San Francisco now known as Silicon Valley. 'It is conventional, and by no means inappropriate, to think of disasters in strictly negative terms, but calamities have also often presented opportunities', writes historian Kevin Rozario in *The Culture of Calamity: Disaster and the Making of Modern America*. 'Americans, especially those in positions of power and influence, have often viewed disasters as sources of moral, political and economic renewal.'[14]

Indeed, natural disasters can be powerful promoters of corporate and free-market interests, argues social activist Naomi Klein in *The Shock Doctrine: The Rise of Disaster Capitalism*, with specific reference to the Indian Ocean earthquake-induced tsunami in 2004. Some thinkers have gone so far as to see earthquakes as blessings in disguise. After the destruction of Lisbon in 1755, the philosopher Immanuel Kant claimed: 'Just as we complain of ill-timed or excessive rain, forgetting that rain feeds the springs necessary in our economy, so we denounce earthquakes, refusing to consider whether they too may not bring us good things.'[15] In 1848, in his *Principles of Political Economy*, John Stuart Mill predicted long-term benefits from such disasters, because they obliterated old stock and encouraged manufacturers to introduce efficiency savings in production processes. From a religious and political perspective, Mahatma Gandhi maintained that a great earthquake in north India and Nepal in 1934 was a warning to caste Hindus against the sin of Untouchability. 'Visitations like droughts, floods, earthquakes and the like, though they seem to have only physical origins, are, for me, somehow connected with man's morals', Gandhi publicly announced.[16]

Since prehistory, human societies have cohabited with seismicity in a 'fatal attraction' (the evocative phrase of geophysicist James Jackson), because

the advantages of living with earthquakes easily outweigh the disadvantages.[17] More than half of the world's largest cities – as many as sixty of them – lie on plate-tectonic boundaries such as the San Andreas fault, in areas of major seismic activity. They include Ankara, Athens, Beijing, Cairo, Caracas, Delhi, Hong Kong, Istanbul, Jakarta, Karachi, Lisbon, Lima, Los Angeles, Manila, Mexico City, Naples, Osaka, Rome, San Francisco, Santiago, Shanghai, Singapore, Taipei, Teheran and Tokyo. Some of them – notably Caracas, Lisbon, Lima, Los Angeles, Manila, Mexico City, Naples, San Francisco, Teheran and Tokyo – have suffered major destruction from earthquakes during the past two or three centuries.

Plate-tectonic boundaries often coincide with coastlines and islands, which have always provided fruitful environments for human settlement – as in California, Chile, Greece, Indonesia, Italy and Japan. At present, the vast majority of Chile's population live in a narrow but fertile strip of land between the Pacific coast on the west and the Andes Mountains in the east, which is a dangerous subduction zone, geologically speaking, in which the Nazca plate of the eastern Pacific pushes its way eastwards and subducts – dives down – beneath the stationary South American plate, thereby generating great earthquakes and thrusting up the Andes. In antiquity, the Greeks and Romans – notwithstanding frequent earthquakes in the Aegean area and in the Italian peninsula – created colonies and empires and enduring monuments: one of which, the Colosseum in Rome, built in the late 1st century AD, stands half-ruined by an Italian earthquake (probably a major one in 1349). In prehistory, some 2 million years ago, tectonic movements in the Dead Sea fault system of Palestine produced a lush and inviting valley in the midst of arid desert that attracted mankind's earliest emigrants from Africa, who eventually created cities such as Jericho, one of the oldest in the world, dating back to the 7th millennium BC.

Important cities destroyed by earthquakes and their subsequent fires have proved to be extraordinarily resilient – unlike villages, which tend to be abandoned or relocated. Indeed, Jericho supports this observation. According to a famous passage in the Bible, Joshua and his people are said to have passed over the flooded River Jordan by unknown means, laid siege to Jericho and captured it on the seventh day after blowing their ram's-horn

trumpets and giving a great shout, which made the city's walls suddenly fall down flat. Almost certainly, Joshua was the beneficiary of an earthquake followed by a landslide, which between them dammed the Jordan and flattened Jericho. Archaeological excavation of the site of Jericho shows that it has been devastated by multiple earthquakes over many centuries; such landslides in the Jordan valley were reported in historical times in AD 1160, 1267, 1534, 1546, 1834 and 1927. An earthquake at Jericho in 31 BC damaged the palace of Herod the Great and provoked the king to reassure his troops that the cause was natural, not divine; the latest one, in 1927, almost totally demolished the modern city. Yet, after each seismic shaking, Jericho was rebuilt.

In classical antiquity, Pompeii, near earthquake-prone Naples, was devastated by an earthquake in AD 62 or 63. The Roman emperor Nero, after visiting the city, recommended that the seismic damage was so bad that Pompeii should be abandoned. But it was instead rebuilt – just in time for Pompeii's permanent destruction by the volcanic eruption of Vesuvius in 79. The trading and pleasure city of Antioch (modern Antakya) on the Mediterranean coast of southeastern Turkey was ravaged by earthquakes in AD 115, 458, 526 and 528, the first of which injured the Roman emperor Trajan, who was compelled to shelter in the city's circus. Antioch, considered in its time to be comparable with Athens, Rome, Alexandria and Constantinople – with a population of perhaps half a million people in the first two centuries AD – was always rebuilt: as many as fifteen times over the past twenty-three centuries. In Persia/Iran, the site of Teheran was damaged or completely destroyed by earthquakes in the 4th century BC, AD 855, 958, 1177 and 1830.

In the modern period, Lisbon was rebuilt after the cataclysm of 1755, as were Tokyo and Yokohama after the Great Kanto earthquake in 1923. In China, the industrial centre of Tangshan was rebuilt after a night-time earthquake in 1976 killed as many as 750,000 sleeping Chinese (while sparing all but seventeen of Tangshan's 10,000 miners working underground). In Central America, the old capital of Guatemala, Antigua, was ruined and rebuilt four times from 1586 in less than 300 years; the capital of Nicaragua, Managua, ten times in less than 200 years. In fact, in recorded history no

city has ever been abandoned as a result of a great earthquake, except for Port Royal in Jamaica, two-thirds of which slid under the Caribbean Sea after an earthquake in 1692, thereby drowning and suffocating some 25,000 of Port Royal's inhabitants in water and sand.

So, earthquake-prone cities – including many capitals – generally recover from seismic catastrophes and frequently prosper. What about societies and nations? Here, the historical record is less consistent and inevitably open to interpretation, debate and dispute.

At one pole, there is the much-quoted observation attributed to historian Will Durant that: 'Civilization exists by geological consent, subject to change without notice'.[18] At the other, there is the influential opinion of the scientist and geographer Jared Diamond, author of *Guns, Germs, and Steel: The Fates of Human Societies* and *Collapse: How Societies Choose to Fail or Succeed*. In the latter book, Diamond almost ignores natural disasters, and totally ignores earthquakes and volcanic eruptions. Both Durant and Diamond are too extreme, in my view. While societies and nations are unquestionably more likely to fail or succeed as a result of human activities, such as warfare or empire-building, they may also be destabilized or developed by great natural forces, such as floods or earthquakes; moreover sciences, such as seismology, can to some extent tip the balance in favour of success against the forces of nature. The problem – and the subject of this book – is, of course, to understand exactly how human agency and great earthquakes have interacted, not only in the short term, but also in the long perspective of history.

Consider a much-debated example from antiquity. Around 1200 BC, there was a catastrophic, apparently simultaneous, collapse of the Bronze Age cultures at an astonishing forty-seven archaeological sites around the eastern Mediterranean, including Mycenae (mainland Greece), Knossos (Crete), Troy (Anatolia) and Armageddon (the Levant). The Bronze Age civilization in Greece was succeeded by a Dark Age, which was apparently illiterate. This lasted for some four centuries until the appearance of Homer's poetry in the 8th century BC, along with the Greek alphabet.

Could earthquakes have been responsible for this collapse? Possibly. Seismologists are certain that the outer walls of Mycenae, directly beneath

its celebrated Lion Gate, were built on top of a fault scarp, which must have been created during a major earthquake. At Knossos, the chief excavator from 1900 until his death in 1941, Arthur Evans, experienced a local Cretan earthquake while digging. At Troy, the excavations were shaken by a major earthquake in 1912. Both Evans and a key excavator of Troy in the 1930s, Carl Blegen, were sympathetic to a seismic interpretation of the Minoan and Trojan archaeological evidence.

However, many current archaeologists are unconvinced. Not being geologically trained, archaeologists tend to miss evidence for seismic damage; and even when the seismic evidence is too plain to ignore, they are inclined to dismiss earthquakes as events with profound ramifications. Most of them prefer to attribute the decline or collapse of ancient societies to war, invasion, social oppression, economic corruption, environmental abuse and so on – rather than natural disasters, 'acts of God'. The idea that a natural disaster might on occasion operate in tandem with human agency – as with the possible earthquake and landslide near Jericho and Joshua's subsequent capture of Jericho – is seen by these archaeologists 'as a capitulation, a sign of a weak theory that must be bolstered by unlikely coincidences', writes a geophysicist and palaeoseismologist, Amos Nur, in *Apocalypse: Earthquakes, Archaeology, and the Wrath of God*.[19]

In Nur's view, by contrast, 'When many similarly oriented walls at a site have fallen in the same direction', as at Jericho, Mycenae and Troy, 'particularly when they have buried grain, gold or other valuables in their fall, the action of an army is an unlikely cause.'[20] While Nur fully recognizes the ambiguous nature of the geological, archaeological and literary evidence for ancient earthquakes – including the many references to them in classical Greek drama (notably the plays of Euripides) and in the Bible (where an earthquake accompanies both the crucifixion and the resurrection of Jesus Christ) – he nonetheless makes a strong case for their importance.

In truth, neither earthquakes on their own nor invasions on their own will account for the Bronze Age collapse around 1200 BC. A more plausible, if less than wholly satisfying, natural-cum-human explanation could be as follows, as argued by classicist Eric Cline in *1177 B.C.: The Year*

Civilization Collapsed. Initially, all of these ancient societies (Mycenae, Knossos, Troy, Armageddon and so on) were weakened not by one giant earthquake and its aftershocks but by a long sequence of earthquakes, in which one earthquake triggered another during the period 1225–1175 BC. This possibility – dubbed an 'earthquake storm' by Nur and others – is supported (on a geological, rather than human, time-scale) by a series of historically attested major earthquakes that struck the eastern Mediterranean area in the middle of the 4th century AD: for example, Sicily, Constantinople and Jerusalem/Petra were each struck in different months of AD 363. Again, during the 20th century AD, there was an exceptionally high level of seismicity in the eastern Mediterranean area, as measured by seismographs between about 1900 and 1980: Turkey alone experienced thirty-two earthquakes of magnitude greater than 6.0. Subsequently, during and after the earthquake storm, suggests Cline, the weakened Bronze Age societies were destroyed by human agency, including seaborne invasions by various groups of marauders, whom archaeologists generally designate as the Sea Peoples.

Earthquakes of the pre-modern world, where historical evidence is thin, occupy Chapter 1 of the book. Then we move on to the modern period (in Chapters 2–11) – including the development of earthquake science after 1750 (Chapters 2, 5 and 6) – where records are comparatively plentiful. Here it is clear that although earthquakes have not had the power to break or make states and civilizations, from time to time they have altered the course of history and determined the fate of nations.

Consider the following great earthquakes of the past two and a half centuries.

In Portugal, the devastation of its capital, Lisbon, by an earthquake in 1755 (see Chapter 3) accelerated the long-term decline of the country in both Europe and the colonial world, caused by its over-reliance on gold revenues from its colony Brazil and the pernicious influence of Jesuit religious orthodoxy. Although the Jesuits were expelled and Lisbon was gradually, and impressively, rebuilt under the near-dictatorship of the marquis of Pombal, the country was economically weakened, especially after Brazil gained its independence in 1822. In Europe as a whole, political, religious,

philosophical and scientific thought were significantly changed by Voltaire's lacerating writings about the Lisbon earthquake. 'By striking at a time when there was a particularly delicate balance of power between church and state, and between science and religion,' notes Nur, 'the earthquake tipped the scales and changed society around the world.'[21]

In Latin America, an earthquake in Venezuela in 1812 (see Chapter 4) destroyed much of the country's buildings including those of its capital, Caracas. The damage happened to be worst in the areas controlled by Simón Bolívar's recently proclaimed First Republic of Venezuela and relatively light in areas sympathetic to the colonial ruler, Spain: a fact immediately exploited by the local Catholic authorities, who supported Spain. By Bolívar's own admission, the earthquake directly precipitated the republic's collapse four months later under attack by Spanish forces, which captured Bolívar and sent him into exile. There he unexpectedly became the leader of a much wider independence movement than the one he had led in Venezuela before the earthquake. Indirectly, therefore, the 1812 earthquake may be said to have led to Bolívar's liberation of Bolivia, Colombia, Ecuador, Peru and Venezuela from Spanish rule in the 1820s.

In Japan, the Great Kanto earthquake in 1923 (see Chapter 7), which lasted for a crippling five minutes, struck as the midday meal was being cooked. The firestorms it ignited left two-thirds of Tokyo and four-fifths of Yokohama in ashes, and cost at least 140,000 lives, including those of many Korean immigrants murdered by Japanese vigilantes. Martial law was required to control the chaos, giving a new degree of authority to the army. The massive cost of rebuilding the cities between 1923 and 1930 created an economic stress and a financial panic. These events together set the scene for a more authoritarian imperial government in 1927, which favoured military intervention in China. Japan's invasion of China (Manchuria) in 1931, along with the worldwide economic depression of the 1930s, led to a pervasive militarization of Japanese society, and eventually to Japan's entry into the Second World War in 1941.

In China, the appalling Tangshan earthquake in 1976 (see Chapter 8) literally shook the deathbed of Chairman Mao Zedong in not-so-far-off Beijing, and figuratively shook up the Communist Party leadership. Though

only 23 seconds in duration, its death toll was the highest for any 20th-century earthquake. Mao's death, just over a month after the disaster, prepared the way for the leadership of Deng Xiaoping from 1978 and the subsequent transformation of China into a world economic power. While the death of Mao was the proximate cause of these pivotal changes, the Tangshan earthquake can be regarded as their catalyst. For the Chinese government's incompetence in dealing with the Tangshan catastrophe exposed Mao's Cultural Revolution as a sham, and undermined the Chinese people's faith in its Maoist government to protect them.

In India, the destruction of towns and cities in the state of Gujarat by an earthquake near Bhuj in 2001 (see Chapter 9) led to the forced resignation of the state's chief minister nine months later, after he had failed to begin effective reconstruction. The next chief minister, Narendra Modi – a Hindu nationalist appointed without an election – responded to the destruction by launching a rapid, uncontrolled, industrialization of Kutch, the area of western Gujarat affected by the earthquake. While consolidating Modi's power base, this economic regeneration also appeared to offer a model for the development of other Indian states. In 2014, during India's national elections, the controversial Modi was easily elected as India's prime minister, largely on the expectations aroused by his economic record in Gujarat, predicated on the destruction caused by the earthquake.

In the Indian Ocean, a massive submarine earthquake off the coast of Sumatra generated a tsunami in 2004 (see Chapter 10), which caused mayhem on the coasts around the Indian Ocean and the loss of about 230,000 lives. The worst affected countries were Indonesia, in particular the province of Aceh in Sumatra, and Sri Lanka, especially its northern and eastern coasts, which are a Tamil-majority region. In both of these areas, a local armed insurgency had long been fighting the country's central government. But whereas in Aceh the tsunami disaster led directly to an enduring peace treaty between the Free Aceh Movement and the Indonesian government, in Sri Lanka the effect was the opposite: the disaster solidified the grip of the Sinhalese nationalist government in Colombo, which went on to annihilate the separatist movement led by the Tamil Tigers with a concerted military attack on the northeast of the island in 2009.

As for the Great East Japan (Tohoku) earthquake in 2011 (see Chapter 11), and the tsunami that overwhelmed the Fukushima Daiichi nuclear power plant, this disaster was described by the then Japanese prime minister as 'the biggest crisis' Japan had encountered since the end of the Second World War.[22] It is too soon to say what its long-term effects will be. However, the earthquake's jolt to the Japanese political system is already evident in the emergence of a nationalist central government at the same time as the rise of stronger local government, especially in the tsunami-affected northeast, and a vigorous national volunteering movement. There have also been worldwide reverberations in the nuclear power industry, as the Japanese government grapples with the clean-up of the wrecked power plant, which is expected to require decades.

Overall, therefore, history suggests that great earthquakes have indeed sometimes been important in the decline, collapse and rebirth of societies. Darwin was right to draw attention to their awesome power in 1835. But he was probably wrong to suggest that mid-19th-century England, given its strong government and industrial and financial resources, not to speak of its extensive colonial empire, would have struggled to rebound from such a hypothetical geological assault. For similar reasons, 20th-century San Francisco and Tokyo rebounded relatively fast from devastating earthquakes. Compare the effects of two major earthquakes in 2010, which were less powerful than those in San Francisco in 1906 and Tokyo in 1923, but still highly destructive. One of them, of magnitude 7.1, struck New Zealand, 40 kilometres (25 miles) from the city of Christchurch, yet caused not a single fatality. The other, of magnitude 7.0, struck Haiti, 25 kilometres (16 miles) from its capital Port-au-Prince, and caused somewhere between 85,000 and 316,000 deaths; the higher figure is the Haitian government's estimate, which is disputed by international aid agencies. The most significant reason for the huge difference in the fatalities in Christchurch and Port-au-Prince was the reinforced construction of buildings in New Zealand, as compared with the unreinforced construction of buildings in Haiti – a fact that of course depends on the very different degree of political, economic, technological and scientific development of New Zealand and Haiti. Where government is weak and resources are poor, Darwin's pessimism may be justified.

The long-term impact of a great earthquake depends on its epicentre, magnitude and timing – and also on human factors: the political, economic, social, intellectual, religious and cultural resources specific to a region's history. As we shall now discover, each earthquake-struck society offers its own particular lesson; and yet, taken together, such earth-shattering events have important shared consequences for the world.