



Port-au-Prince after the devastating 2010 earthquake that killed more than 85,000 Haitians.

GEOPHYSICS

Vast forces underfoot

Andrew Robinson examines three books that see seismicity as both grimly destructive and, in some contexts, culturally energizing.

A blink in geological time — 150 years — has passed since Jules Verne published his fantasy *Journey to the Centre of the Earth* (see D. Chatelain and G. Slusser *Nature* **513**, 169–170; 2014). Half a century later, geologist and meteorologist Alfred Wegener published his radical theory of continental drift, *The Origin of Continents and Oceans* (see T. Nield *Nature* **526**, 192–193; 2015). And half a century after that, in 1965, the theory of plate tectonics — partly inspired by Wegener — was established by geophysicist John Tuzo Wilson among others.

In the subsequent half-century, exploration of the Solar System has revealed that Earth is the only planet in it with a global system of plate tectonics. Satellites in the US Global Positioning System monitor plate movements with an accuracy of a few millimetres. But our understanding of Earth's

Journey to the Centre of the Earth: The Remarkable Voyage of Scientific Discovery into the Heart of Our World

DAVID WHITEHOUSE
Weidenfeld & Nicolson: 2015.

Earthquake Time Bombs

ROBERT YEATS
Cambridge University Press: 2015.

Impact of Tectonic Activity on Ancient Civilizations: Recurrent Shakeups, Tenacity, Resilience, and Change

ERIC R. FORCE
Lexington: 2015.

mantle and core is much less advanced. The deepest borehole penetrates just 12,262 metres, two-thousandths of Earth's radius. Reliant mainly on seismographic monitoring, modelling and post-quake analysis, geophysicists and seismologists remain

perplexed about the exact structure of the inner core and the precise cause of earthquakes. Developments in seismology since the 1930s, when Charles Richter invented his local-magnitude scale, have ranged from laboratory fault-friction experiments to global seismic tomography. But our ability to predict the timing, location and magnitude of earthquakes has scarcely progressed.

Now, three books examine earthquakes from distinct angles. In his *Journey to the Centre of the Earth*, astronomer and BBC science broadcaster David Whitehouse takes the reader on a scientific journey from crust to core in a book inspired by Verne's, but making slight reference to it. Seismologist Robert Yeats, in *Earthquake Time Bombs*, focuses on the crust, and how to protect vulnerable conurbations — his “time bombs” — from probable seismic shocks. And geologist ▶



A first-century-AD relief in Pompeii, Italy, shows the Temple of Jupiter tilting after an earthquake in AD 62 or 63.

► and geoarchaeologist Eric Force investigates earthquakes from the third millennium BC in *Impact of Tectonic Activity on Ancient Civilizations*, theorizing that they stimulated trade and helped to shape civilizations.

Whitehouse's account is the most readable and wide-ranging, although it is inevitably speculative. "We will reach the distant stars before we reach the centre of the Earth," he writes, after descending more than 1,000 metres into one of the deepest mines in Europe, the Boulby potash mine in northeast England. He is also the most adept at mixing the history of Earth science — beginning with Edmond Halley's maritime expedition to measure Earth's magnetic field around 1700 — with comments by current researchers. One of them admits that "everything" about the inner core — structure, anisotropy, topography and dynamics — "is getting increasingly complex as we get more data".

However appealing, Whitehouse's account contains errors. For instance, the disastrous 1906 San Francisco earthquake, in which more than 3,000 people died, did not prompt the introduction of "building and emergency regulations"; those came decades later in California. Indeed, San Franciscans did their best to blame the city's destruction on the fire started by the earthquake and to carry on with 'business as usual'. Nor did seismologist Beno Gutenberg, mentor of Richter, flee persecution in Germany in 1933 for a job at the University of California. He left in 1930, before Adolf Hitler came to power, and settled at the California Institute of Technology in Pasadena, along with a visiting Albert Einstein.

Yeats's book is a follow-up to his magnum opus, the specialist *Active Faults of the World* (Cambridge University Press, 2012). *Earthquake Time Bombs* aims to reach a wider audience. Writing that the "next great earthquake will be a disaster, but failing to prepare for it will lead to a catastrophe", he recounts how in early 2010 he told a *Scientific American* reporter that Port-au-Prince

should be regarded as a time bomb. Its swelling population occupied dilapidated slums adjacent to a plate-boundary fault that had not sustained a major earthquake since the mid-eighteenth century. A week after he made his comments, a magnitude-7 earthquake destroyed the Haitian capital, killing at least 85,000 people (the government put the figure at more than 300,000), mainly as a result of inadequate and corrupt building practices (R. Bilham *Nature* 502, 438–439; 2013). Yeats had not, of course, predicted the quake. He was simply aware of research on the fault published in 2008 by Eric Calais and his colleagues (D. M. Manaker *et al. Geophys. J. Int.* 174, 889–903; 2008) These researchers had privately alerted the Haitian government, but advised that they could not predict the timing of the recurrence.

Sixty of the world's largest cities lie on plate boundaries and are at risk from interplate earthquakes. Yeats duly discusses the usual suspects, such as San Francisco, Tokyo, Istanbul and Santiago. But he also explores less familiar threats, including the Cascadia subduction zone (Seattle, Portland and Vancouver), where he lives, along with Tehran, Kabul, parts of the Himalayan region, Manila, Caracas, Wellington and the East African Rift Valley. Surprisingly, he neglects the hazard from intraplate quakes that occur away from boundaries, including that in Gujarat, India, in 2001 and, most famously, the 1811–12 earthquakes in Missouri in the middle of the North American plate. The Missouri quakes have provoked much debate among leading US seismologists such as Susan Hough and Seth Stein, author of *Disaster Deferred* (Columbia University Press, 2010), a book that Yeats does not mention. He concludes

with convincing grimness that only California, Japan, Chile and New Zealand have taken the earthquake hazard seriously.

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Where Yeats expounds on the destructive power of quakes, Force posits that they may have rocked the cradles of past civilizations. High tectonic activity has accompanied the birth and growth of many ancient civilizations in the Middle East, Greece and Italy and, to a lesser extent, the Indus Valley and China. During the second and first millennia BC around the Mediterranean Sea, the Minoan, Mycenaean, Greek, Etruscan and Roman civilizations arose during eras of major seismic activity in their regions. No comparable cultures developed on the relatively inactive coasts of Spain, France and Libya, observes Force. He suggests that frequent tectonic activity was a "long-term cultural stimulant", forging ancient communities that were resilient, cooperative, innovative and outgoing, and where "elders would be passing on an expectation of change to younger generations".

It is a tantalizing thesis, which Force pursues tenaciously and with considerable skill. However, the book perhaps goes too far in its claim for the dominance of seismic activity in the development of civilizations. If the hypothesis is correct, how did Egypt, which had (and has) relatively low tectonic activity, produce a major civilization? Surely, climate, coasts, rivers, fertile soil and supplies of water, minerals, building materials and fuel are also key, even if some of these factors are also influenced by tectonic activity.

Nevertheless, Force's speculation remains an intriguing possibility. Today, both Silicon Valley and Hollywood lie on the San Andreas fault. Just a coincidence? Or is the hidden cause of these powerhouses of imagination and innovation that the region has frequently been "all shook up"? ■

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