Disciplining the Earth: Earthquake Observation in Switzerland and Germany at the Turn of the Nineteenth Century

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ABSTRACT

This article examines how, in late nineteenth-century Switzerland and Germany, the established earthquake discourse was socially reshaped and, in turn, helped change the way people conceived of social reality. Scientists broke with the tradition of enlightened earthquake discourse in that they argued that earthquake research was about the regular and statistically frequent, and not primarily about the exceptional or hazardous. Their attitude was sustained by the idea of social contingency that had come to define Western societies' self-perception. The idea started to transform the supposed accidental and threatening character of earthquakes. It suggested that the individual and social scopes of action had broadened and mattered, that 'progress' was shapeable. In the face of nature's uncertainties, seismologists were eager to highlight the opportunity for social action offered by moderate quakes and instrument-based observation.

Earthquake research added to another key feature of Western modernity: arguably, the new pictures of the earth such as global earthquake belts and the shell-like construction of the inner earth suggested by seismology contributed to the social and cultural processes of globalisation at work at the turn of the twentieth century. To the practitioners, the seismic survey of the whole earth, whether undertaken on a micro or a macro scale, offered what could be called a material substrate for the growing awareness among Western nation states of being globally embedded and interconnected in many terms: political, economic, scientific and cultural.

KEYWORDS

Contingency, globality, seismology, earthquake research, history of science

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INTRODUCTION

For most of their history, earthquakes, the sudden upheavals of the earth, have epitomised the unpredictable and unapologetic force of nature.[1] Without warning, earthquakes destroy whole villages or cities leaving both citizens and authorities with the shock of destruction and death, the burden of disaster relief and the threat of recurrence. The Lisbon earthquake of 1755 was perceived as a catastrophic event which transformed European culture: the Enlightened earthquake discourse addressed universal questions of theodicy, human vulnerability to the natural world and the foundation of reason.[2] In closer study of earthquakes, the unexpected and fast-spreading shocks defied individual efforts at observation and description. Collaboration had long been acknowledged as an important precondition for progress.[3] In the late nineteenth century, the prolific but scattered endeavours made in the observation and recording of earthquakes began to resonate with each other. Modern earthquake science or seismology, as it was called among English and French scientists in the 1880s, came into being.[4] Geologists and geophysicists built observational networks at different sites in the world. Driven by questions of how and why earthquakes occurred, how the tremors travelled through the earth and what information about the constitution of the earth's interior might be deduced from the behaviour of earthquake waves, seismological knowledge began to be produced.

In Switzerland, Albert Heim (1849–1937) engaged in macroseismic research, the observation of felt earthquakes, after the Eastern cantons of the country were shaken in 1877. The professor of geology at the Swiss Federal Polytechnic in Zurich sent out an inquiry through newspapers and devised several questions, seeking information about the time of the shock, its direction, the damage it caused to houses, etc. The 207 letters Heim received soon afterwards were the prelude to the development of a permanent national network for macroseismic

1. I would like to thank the two guest editors of this issue, two anonymous referees, Sabine Höhler, Michael Bürgi, Conevery Bolton Valencius, and Grace Yen Shen for helpful comments on earlier drafts of the article.

2. Christiane Eifert, 'Das Erdbeben von Lissabon 1755. Zur Historizität einer Naturkatastrophe', *Historische Zeitschrift* **274** (3/2002): 633–64; Theodore E. D. Braun and John B. Radner, eds. *The Lisbon Earthquake of 1755: Representations and Reactions* (Oxford: Voltaire Foundation, 2005).

3. Peter Merian, *Über die in Basel wahrgenommenen Erdbeben nebst einigen Untersuchungen über Erdbeben im Allgemeinen* (Basel: Wieland, 1834), 1; Otto Volger, 'Untersuchungen über das letztjährige Erdbeben in Central-Europa', *Petermanns Geographische Mitteilungen* **1** (3/1856): 85–102 (85).

4. Fernand de Montessus de Ballore, 'La Suisse sismique', *Archives des sciences physiques et naturelles 3e pér.* **28** (1892): 31–9; Anonymous, 'Review of "The Seismological Journal of Japan" by John Milne', *Science*, **22** (545/1893): 25–6; David Oldroyd, *Thinking about the Earth: A History of Ideas in Geology* (London: Harvard University Press, 1996); 224–47; Johannes Schweitzer, 'The Birth of Modern Seismology in the Nineteenth and Twentieth Centuries', *Earth Sciences History* **26** (2/2007): 263–79.

observation. This included the foundation of the Swiss earthquake committee in 1878 and the massive enrolment of citizens. In Imperial Germany in 1889, Ernst von Rebeur-Paschwitz (1861–1895) identified the disturbances spoiling the seismograms of the self-registering pendulums he had set up at Potsdam and Wilhelmshaven to study the attraction of the moon as earthquake waves. An article in *Nature* made him think that the waves had their epicentre in Japan. Reporting his findings to the scientific community, Rebeur-Paschwitz was the first to suggest that the shock waves of strong earthquakes could be detected with the help of instruments based anywhere in the world.[5] Instrument-based seismology came to be known as microseismology.

Considering the many unsolved geological and geophysical problems, the movement from the local and regional to the global scale seemed a natural step to many researchers. Rebeur-Paschwitz, for instance, proposed an international seismological association in 1895. Emil Wiechert (1861–1928), in turn, campaigned for an observatory in the new German colony of Samoa. The professor of geophysics at Göttingen University held that microseismic data generated in the southern hemisphere would provide evidence, when related to the data recorded at home, for wave propagation in the deeper layers of the earth.[6] After 1899, Germany started to coordinate instrument-based earthquake studies at the *Kaiserliche Hauptstation für Erdbebenforschung* in Strasbourg. In 1903, the central bureau of a nascent international seismological association was

5. F. P. W. Rebeur-Paschwitz, 'The earthquake of Tokio, April 18, 1889', *Nature* **40** (1889): 294–5; James Dewey and Perry Byerly, 'The early history of seismometry (to 1900)', *Bulletin of the Seismological Society of America*, **59** (1/1969): 183–227 (208–9). Unfelt pulsatory movements of the ground had been registered in Japan from the mid 1880s; see Gregory Clancey, *Earthquake Nation. The Cultural Politics of Japanese Seismicity, 1868–1930* (Berkeley: University of California Press, 2006), 72, quoting John Milne (1850–1913), a British geologist in the employ of the Japan: 'We shall see around us a mighty forest of pendulums, springs, and delicately balanced columns.' While the movements were recognised to have originated at a great distance, the centres from which they sprang were not determined; see John Milne, 'Recent advances in seismology', *Proceedings of the Royal Society of London. Series A, Containing Papers of a Mathematical and Physical Character* **77** (518/1906): 365–76 (367).

6. Emil Wiechert, 'Entwurf einer Denkschrift über seismologische Beobachtungen in den deutschen Kolonien', in *Verhandlungen der Zweiten Internationalen Seismologischen Konferenz*, Beiträge zur Geophysik. Ergänzungsband 2, ed. Emil Rudolph (Leipzig: Engelman, 1904), 313–18 (313–14); Emil Wiechert, 'Die Erdbebenforschung, ihre Hilfsmittel und ihre Resultate für die Geophysik', *Physikalische Zeitschrift* **9** (1908): 36–47 (43); Lewis Pyenson, *Cultural Imperialism and Exact Sciences. German Expansion Overseas 1900–1930*, Studies in History and Culture Vol. 1 (New York, Bern, Frankfurt a. M.: Lang, 1985) 38; on the German colonial state in Samoa, see George Steinmetz, *The Devil's Handwriting. Precoloniality and the German Colonial State in Qingdao, Samoa, and Southwest Africa* (Chicago: University of Chicago Press, 2007) 317–58.

established in Strasbourg.[7] In 1904, the year the International Association was founded, 104 seismographic stations were working worldwide.[8]

In large part, the scientific investigation of earthquakes developed in response to disaster. In earthquake prone regions like Japan, California, or central Italy, it was one attempt among others, civic and political, to cope with catastrophe. Mitigating the effects of earthquakes was the main purpose of research.[9] In Switzerland and Imperial Germany, earthquakes happened regularly but seldom caused severe devastation. Minor but regular shocks stood in sharp contrast to the episodic, interrupted quality of earthquake observations during major earthquake events. The lack of severe damage and the relative frequency of macroseismic events helped Swiss and German scientists see earthquakes as a valuable source of geological and geophysical information rather than catastrophes to be mitigated. Geologists and geophysicists sought to establish continuous observation and generate a steady flow of data. They pursued a twofold aim. First, they wanted to determine regions of greater or lesser stability. Second, they investigated the 'seismicity of the whole earth':[10] The continuous stream of data was to reflect all the elastic waves rolling under the earth and along its surface and exhibiting certain patterns of propagation.

In so doing, earthquake research in Germany and Switzerland explicitly broke with the tradition of enlightened earthquake discourse. It was, by its own standards, about the regular and statistically frequent, and not primarily about the exceptional or hazardous. This article argues that, in this view, earthquakes exemplified and supplemented the modern experience of globality burgeoning at the turn of the twentieth century. The 'seismic survey of the whole earth',[11] whether on a micro or a macro scale, offered what could be called a material substrate for the growing awareness among Western nation states of being globally embedded and interconnected in many terms: political, economic, scientific and cultural. The patterns emerging from the collection of seismograms or macroseismic maps pointed to the inner structures of the globe and emphasised its oneness. 'It is still quite surprising', the Vienna geologist Eduard Suess explained in 1907, 'to see a seismic event in Japan inscribing itself at

7. Georg Gerland, 'Zirkular des Zentralburaus der Internationalen Seismologischen Assoziation', *Astronomische Nachrichten* **172** (3-4/1906): 63–4.
8. Jean-Pierre Rothé, 'Fifty Years of History of the International Association of Seismology (1901-1951)', *Bulletin of the Seismological Society of America* **71** (3/1981): 905–23; August Sieberg, *Handbuch der Erdbebenkunde* (Braunschweig: Vieweg, 1904), 327–8.
9. Judith Goodstein, 'Waves in the Earth: Seismology Comes to Southern California", *Historical Studies in the Physical Sciences* **14** (2/1984): 201–30; Carl-Henry Geschwind, *California Earthquakes: Science, Risk, and the Politics of Hazard Mitigation* (Baltimore, London: Johns Hopkins University Press, 2001); Clancey, *Earthquake Nation*.
10. Georg Gerland, 'Die Kaiserl. Hauptstation für Erdbebenforschung in Strassburg und die moderne Seismologie', *Beiträge zur Geophysik* **4** (1900): 427–72 (427).
11. Milne, 'Recent Advances in Seismology', 367.

a central European seismological observatory.'[12] A popular textbook on earthquakes stated that earthquakes often 'grapple the earth as a whole, they make the whole earth tremble'.[13] Some version of the idea that a global seismicity existed had led to the collection of earthquake catalogues in earlier times and the substantiated hypothesis prompted the building of worldwide observational networks circa 1900.

To be sure, the scientists acknowledged that the seismicity of the earth had unevenly distributed consequences: the long distances shock waves travelled through the earth and along its surface and the effects of refraction and reflection they experienced diminished what, at their point of origin, might well unfold as a catastrophe.[14] Earthquakes and the seismic activity of the earth remained events beyond human decision or control because neither the macroseismic nor the microseismic records demonstrated predictability in the temporal occurrence or magnitude of earthquakes. In Germany and Switzerland, however, a source of contingency other than nature or divine order had gained acceptance and reshaped the notion of uncertainty:[15] the social realm produced its own contingencies. Contemporary thinking had come to acknowledge that reality might have been entirely different had people not acted as they did.[16] This attitude reflected that, in the late eighteenth and early nineteenth centuries, something about the experience of time had altered. The industrial and political revolutions in Britain and France had conveyed, among contemporaries, the sense of rapid change and the conviction of living in a new or modern time. The experience of an epochal break estranged European societies from their past, but also allowed for the possibility of radically historicising the idea of time:[17] 'A future that transcended the hitherto predictable' had emerged in the political and social thinking of Western societies.[18] The future was no longer

12. Eduard Suess, 'Préface', in: *La science séismologique*, ed. Fernand de Montessus de Ballore. (Paris: Armand Colin, 1907), VI.

13. M. Wilhelm Meyer, *Erdbeben und Vulkane* (Stuttgart: Franckh, 1908), 5 (emphasis in the original).

14. Ernst von Rebeur-Paschwitz, 'Vorschläge zur Errichtung eines internationalen Systems von Erdbeben-Stationen', *Beiträge zur Geophysik* **2** (1895): 773–82 (773).

15. See Hans Blumenberg, 'Kontingenz', in: *Religion in Geschichte und Gegenwart: Handwörterbuch für Theologie und Religionswissenschaft* (Tübingen: Mohr Siebeck, 1959, third ed.) 1793–4.

16. Michael Makropoulos, 'Kontingenz. Aspekte einer theoretischen Semantik der Moderne', *Archives Européennes de Sociologie* **XLV** (3/2004): 369–99 (371); Niklas Luhmann, 'Kontingenz als Eigenwert der modernen Gesellschaft', in *Beobachtungen der Moderne*, ed. Niklas Luhmann (Opladen: Westdeutscher Verlag, 1992). 93–128.

17. Reinhart Koselleck, 'Einleitung', in *Geschichtliche Grundbegriffe. Historisches Lexikon zur politisch-sozialen Sprache in Deutschland* 1, ed. Otto Brunner et al. (Stuttgart: Klett-Cotta, 1972), XIII-XXVII; Reinhart Koselleck, 'Das achtzehnte Jahrhundert als Beginn der Neuzeit', in: *Epochenschwelle und Epochenbewusstsein*, ed. Reinhart Herzog and Reinhart Koselleck (München: Fink, 1987) 269–82.

18. Reinhart Koselleck, *Futures Past: On the Semantics of Historical Time*, transl. Keith Tribe (Cambridge, Mass.: Columbia University Press, 1985) 17.

a mere extension of past experiences. It was unknown. This new unpredictability sharpened the perception that the individual and social scopes of action had broadened and mattered, that 'progress' was shapeable. This article argues that the idea of social contingency affected perceptions of nature and started to transform the accidental and threatening character of earthquakes. In the face of nature's uncertainties, seismologists were eager to highlight the opportunity for social action offered by moderate quakes and instrument-based observation. Sections one and two discuss the concepts of globality and contingency in view of earthquake research. The subsequent parts of the article pursue how the collective experiences of globality and contingency were applied to the building of macroseismic and microseismic observation networks and, at the same time, took shape in and through them.

WESTERN IMAGES AND SEMANTICS OF THE EARTH

Throughout its iconographic history, the earth has represented either a natural whole or a global order.[19] Scientific travelling in the early and mid-nineteenth century was driven by measuring the globe according to all conceivable parameters and plotting global 'isolines'; European scientists collaborated in simultaneous geomagnetic and meteorological observations, starting in the 1830s and 1840s, and visualised the earth's magnetic field. Even if the comprehensiveness of these endeavours remained an illusion, their unifying gaze over the earth covered up the gaps in data and theory.[20] In the late nineteenth century, the idea of wholeness

19. Throughout the ages, representations of the globe have served quite different purposes. From a European perspective, it has been, more than anything else, a symbol of Christian world order or imperial commerce and culture. Art historians analysed the medieval *mappae mundi* as representing both empirical observations and 'moral geographies', David Woodward, 'Medieval Mappaemundi', in *History of Cartography Vol. 1 Cartography in Prehistoric, Ancient, and Medieval Europe and the Mediterranean*, ed. David Woodward and John Brian Harley (Chicago: University of Chicago Press, 1987) 286–370. Historians of cartography showed how the practice of synthesising the world by mapping the spherical earth shaped modern knowing and rationalised the geographic space, see Jerry Brotton, 'Terrestrial Globalism: Mapping the Globe in Early Modern Europe', in *Mappings*, ed. Denis Cosgrove (London: Reaktion Books, 1999) 71–89 (74–5); Denis Cosgrove, *Apollo's Eye. A Cartographic Genealogy of the Earth in the Western Imagination* (Baltimore and London: Johns Hopkins University Press, 2001). Historians of science and technology elaborated the meaning of the 'terraqueous globe' for early modern cosmography and exploratory expeditions: see Roy Porter, 'The Terraqueous Globe', in *The Ferment of Knowledge. Studies in the Historiography of Eighteenth-century Science*, ed. George S. Rousseau and Roy Porter (Cambridge, New York: Cambridge University Press, 1980), 285–324; Klaus A. Vogel, 'Cosmography' in *Early Modern Science*, The Cambridge History of Science, 3, ed. Katharine Park and Lorraine J. Daston (Cambridge, New York: Cambridge University Press, 2006), 469–96; Klaus A. Vogel, 'European Expansion and Self-Definition', ibid. 818–39.

20. On the 'Humboldtian sciences' see Susan Faye Cannon, *Science in Culture: The Early Victorian Period* (Folkestone: Dawson Publishing, 1978), 73–110; Michael Dettelbach,

was again fostered and transformed by the swift expansion in geological and geophysical knowledge. In 1886, the International Geodetic Conference enlarged its work to extend beyond Europe's borders, aiming for an exact measurement of the earth for the economic and scientific purposes of the industrialised world. Disciplinary shifts carved out new space for geophysical research.[21] German geographers, for instance, urged their colleagues to exclude the social sciences from geography altogether and focus instead on the 'planetary wholeness' of the earth.[22] This is how Georg Gerland (1833–1919), professor of geography at the University of Strasbourg, renamed as the Kaiser-Wilhelm-Universität following the Franco-Prussian war in 1871, lobbied successfully for the establishment of the *Kaiserliche Hauptstation für Erdbebenforschung*.

New knowledge about the earth and modern techno-scientific images of the globe were not provided by science alone. Science was itself embedded in political and economic endeavours of worldwide scope. European societies had entered a new stage of globalisation brought about by an ever-growing tide of goods and shaped by cooperation among nation-states and international initiatives.[23] A new sense of globality developed, supplanting earlier ideas of the wholeness of the earth. Geological and geophysical research facilities were entangled with national and global infrastructures, as was the mass communication of scientific news. As mentioned above, only Rebeur-Paschwitz's careful following of international newspapers and journals had enabled him to link the locally

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'Humboldtian Science', in: *Cultures of Natural History*, ed. N. Jardine et al. (Cambridge, New York: Cambridge University Press, 1996), 287–304; on the geomagnetic endeavour see Fabien Locher, 'The Observatory, the Land-based Ship and the Crusades: Earth Sciences in European Context, 1830–50', *The British Journal for the History of Science* **40** (4/2007): 491–504.

21. Gregory A. Good, 'The Assembly of Geophysics: Scientific Disciplines as Frameworks of Consensus', *Studies in History and Philosophy of Science* **31** (3/2000): 259–92 (272–80).

22. Georg Gerland, 'Vorwort der Herausgebers', *Beiträge zur Geophysik. Abhandlungen aus dem geographischen Seminar der Universität Strassburg* **1** (1887): I–LIV; Gerland, 'Die Kaiserl. Hauptstation für Erdbebenforschung in Strassburg und die moderne Seismologie', 428.

23. Jürgen Osterhammel, *Die Verwandlung der Welt. Eine Geschichte des 19. Jahrhunderts* (München: Beck, 2009), 13–14; Elisabeth Crawford et al. 'The Nationalization and Denationalization of the Sciences: an Introductory Essay', in: *Denationalizing Science. The Contexts of International Scientific Practice*, ed. Elisabeth Crawford et al. (Dordrecht: Kluwer Academic Publishing, 1993), 1–42 (13); Peter J. Hugill, *Global Communications since 1844. Geopolitics and Technology* (Baltimore and London: Johns Hopkins University Press, 1999); Martin H. Geyer, 'One Language for the World: the Metric System, International Coinage, Gold Standard, and the Rise of Internationalism, 1850–1900' in: *The Mechanisms of Internationalism*, ed. Martin H. Geyer and Johannes Paulmann (Oxford, New York: Oxford University Press, 2001); Cornelius Torp, 'Weltwirtschaft vor dem Weltkrieg. Die erste Welle ökonomischer Globalisierung vor 1914', *Historische Zeitschrift* 279 (2004), 561-609; Miloš Vec, *Recht und Normierung in der Industriellen Revolution. Neue Strukturen der Normsetzung in Völkerrecht, staatlicher Gesetzgebung und gesellschaftlicher Selbstnormierung*, Recht in der Industriellen Revolution 1 (Frankfurt am Main, 2006).

recorded seismograms to earthquake catastrophes far away.[24] A decade later, a textbook on geophysics gave credence to mass media information, contrasting it with fanciful or, as the author saw it, pre-modern attempts at an explanation: 'Volcanic eruptions and earthquakes! These two words are still stimulating all kinds of imagination, although the global telegraph has acquainted us with the facts!'[25] During their heyday in the nineteenth and early twentieth centuries, scientific travel-writing and reports of world exploration reflected the enhanced sense of globality. Fictitious travel writing took the scientific frontiers as a subject:[26] Jules Verne's novels, *Voyage au centre de la Terre* (1864) and *De la Terre à la Lune* (1865), for instance, depicted the earth as an immense sphere whose form was to be grasped only through interstellar flight and whose core remained to be explored.[27]

Imagining the globe was a common exercise in the sciences of geophysics and geology at the turn of the twentieth century. Whenever geologists or seismologists lectured on earthquakes, they instructed their audience to practice visualising the globe in their mind's eye, zooming in and out. 'If we looked down at the earth from high above', the Swiss geologist Hans Schardt explained to his students in 1913, 'it is a perfectly regular sphere because the differences in altitude of the earth's crust barely amount to more than a four-thousandth part of the Earth's radius. In other words, if we were to take a globe with a radius of

24. Rebeur-Paschwitz, 'Vorschläge zur Errichtung eines internationalen Systems von Erdbeben-Stationen', 773.

25. August Sieberg, *Der Erdball. Seine Entwicklung und seine Kräfte, gemeinverständlich dargestellt* (Eßlingen and München: Schreiber, 1908), XV; Suess, 'Préface', V. Earthquakes can be seen as a material substrate similar to the eruption of the volcano Krakatau in 1883 which was followed by three types of global propagation: a pressure wave, a news wave, and a slowly expanding cloud of dust and aerosols causing spectacular red sunsets; see Matthias Dörries, 'Global Science: the Eruption of Krakatau', *Endeavour*, **27** (3/2003): 113–16 (113), and Matthias Dörries, 'Krakatau 1883: Die Welt als Labor und Erfahrungsraum', in *Welt-Räume. Geschichte, Geographie und Globalisierung seit 1900*, ed. Sabine Höhler and Iris Schröder (Frankfurt a. M.: Campus, 2005), 51–73; see also Paul Edwards, 'Meteorology as Infrastructural Globalism', *Osiris* **21** (2006): 229–50; and James Rodger Fleming et al., eds. *Intimate Universality. Local and Global Themes in the History of Weather and Climate Scaling Down* (Sagamore Beach: Science History Publications, 2006) on the emergence of the concept of globality with an emphasis on the field sciences and physical sciences.

26. Casey Blanton, 'Literary Travel Narratives', in: *The Oxford Companion to World Exploration*, ed. David Buisseret (Oxford, New York: Oxford University Press, 2007), 309–11 (309-10).

27. On the semantics of the earth in the decade of interstellar flights, i. e. the decade of the Apollo space missions, when global environmental concerns converged with questions of international security, see Paul Edwards, *The Closed World. Computers and the Politics of Discourse in Cold War America* (Cambridge, Mass.: MIT Press, 1996); Sheila Jasanoff, 'Image and Imagination: The Formation of Global Environmental Consciousness', in: *Changing the Atmosphere. Expert Knowledge and Environmental Governance*, ed. Clark A. Miller and Paul Edwards (Cambridge, Mass.: MIT Press, 2001), 309–37; Sabine Höhler, '"Spaceship Earth". Envisioning Human Habitats in the Environmental Age', *GHI Bulletin* **42** (2008): 65–85.

one metre, the difference between the highest mountains and the deepest point of the sea-floor would be just four tenths of a millimetre, a distance undistinguishable to the naked eye.'[28] Emil Wiechert, giving a talk at the Göttingen Women's Association, explained the magnitude of the earth as follows: 'The deepest borehole ever drilled is about 2 km long. Now, the earth's centre lies at a depth of 6370 km! … Think of a sphere of a diameter of 13 m. The borehole of 2 km would be represented by a stitch penetrating the sphere by 2 mm only.'[29] The technical exercise of scaling up and down was a variation on older, more philosophical traditions of imagining the earth. As a figurative expression, aiming to express elevation above worldly affairs, the planet's insignificance, a mere 'point in the immeasurable universe',[30] had had a sanctioned presence in essays on astronomy, natural philosophy, theology and emblematic baroque pictures. The earth had been evoked as small by comparison with the godly universe or the solar system: 'One thinks of the heavens and the earth as two concentric spheres, with the earth being infinitely small or only being a point compared to the heavens.'[31] The semantics of globality were deeply rooted in the image of the earth as a planetary body.

CONTINGENCIES OF THE SOCIAL REALM

Earthquake observation around 1900 helped shape and corroborate the modern experience of globality. It also testified to the experience of contingency, which contemporaries felt was another determining feature of modern society. In his *Cosmos,* Alexander von Humboldt had connected the contingent character of earthquakes to the question of whether it was even possible to know the world. Recalling a trope forged in the aftermath of the Lisbon earthquake, he claimed that earthquakes shattered the fundamental 'contrast between the mobility of water and the immobility of the soil on which we tread' and thus destroyed 'the

28. Archives ETH papers Hans Schardt, Hs 389:603, Erdbeben.

29. Emil Wiechert, 'Was wissen wir von der Erde unter uns?', *Deutsche Rundschau* **33** (1907): 376–94 (378).

30. Alexander von Humboldt, *Cosmos: A Sketch of a Physical Description of the Universe* (New York: Harper & Brothers, 1860), 164, quoting Pliny and also Columbus: 'el mundo es poco'; Albert Heim, *Über die Stauung und Faltung der Erdrinde. Eine kurze Zusammenfassung der wichtigsten Resultate aus des Verfassers Werk: 'Untersuchungen über den Mechanismus der Gebirgsbildung*' (Basel: Schwabe, 1878), 33. On the globe as a *vanitas* emblem see the entry 'vanitas' on: Grove Art online (http://www.oxfordartonline.com/subscriber/article/grove/art/T087870 Accessed 9 March 2009).

31. Johann Samuel 'Traugott Gehler, Erdkugel, künstliche', in *Physikalisches Wörterbuch oder, Versuch einer Erklärung der vornehmsten Begriffe und Kunstwörter der Naturlehre: mit kurzen Nachrichten von der Geschichte der Erfindungen und Beschreibungen der Werkzeuge begleitet: in alphabetischer Ordnung*, ed. Johann Samuel Traugott Gehler (Leipzig: Schwickert, 1787–1795); see also Meyer, *Erdbeben und Vulkane*, 6, who asserted that by a 'cosmic scale', the trembles of the earth were 'evanescent small'.

illusion of a whole life'.[32] This contention notwithstanding, earthquake events did not, in the second half of the nineteenth century, shake the cognitive foundations of a (scientist's) 'whole life' anymore. Rather they made a strong case for the insight that events might or might not occur, and that they might always occur differently. The characterisation of modern life as contingent had gained wide acceptance. In a way, natural hazards were rationalised by the idea that the whole course of history was contingent. Once again, literature had grasped the broadening meaning of contingency early on. Heinrich von Kleist's 1807 novella 'The Earthquake in Chile' persuasively claimed that there were alternatives to the actual progress of events. In the novella, both sources of contingency, nature and society, have their share in driving the plot.

The story of the two lovers, Josephe and her tutor Jeronimo, is set in Santiago at the time of the great earthquake of 1647. When Josephe's father found out about their illicit liaison, he banished his daughter to a convent. The love affair continued, however, and when Josephe gave birth to Jeronimo's child, she was condemned to death, while Jeronimo was put in prison. The story opens with Jeronimo on the point of hanging himself in despair when a violent earthquake destroys the prison and allows him to escape. Josephe, for her part, is about to be beheaded just when the earthquake strikes, and, in the resulting confusion, she too is able to escape. What is a terrible disaster for 'the world'[33] turns out to be a fortunate moment for the lovers who eventually meet in the outskirts of the city. Saved from execution and reunited with both her child and her lover, Josephe spends the night in an idyllic, Edenic valley. The next day, the couple resolve to emigrate to Spain and start a new life. However, a spirit of altruistic co-operation, crossing the boundaries of class, spreads among the survivors in the valley. It nurtures the lovers' hope that the earthquake might have overturned the social order and sanctioned their love, and that they would be forgiven. However, society has no intention of self-reform. The suspended death sentence is carried out, although in very different circumstances. Jeronimo and Josephe attend a thanksgiving mass. In his sermon, the priest interprets the earthquake, conventionally, as God's punishment for man's wickedness. Among the manifold sins, he includes the couple's illicit relationship.[34] The churchgoers recognize

32. Humboldt, *Cosmos*, 1860, 215–16; Volger, ‚Untersuchungen über das letztjährige Erdbeben in Central-Europa', 85, made the same point.

33. Heinrich von Kleist, *Das Erdbeben in Chili*, in: *Positionen der Literaturwissenschaft. Acht Modellanalysen von Kleist 'Das Erdbeben in Chili'*, ed. David E. Wellbery (München: Beck, 2007, 5th ed.), 16.

34. On 18th-century sermons interpreting earthquakes as a sign of wrath or warning of God see Monika Gisler, *Göttliche Natur? Formationen im Erdbebendiskurs der Schweiz des 18. Jahrhunderts* (Zürich: Chronos, 2007); on the sermons as ready-made institutional patterns of coping with disaster see Bernd Hamacher, 'Strategien narrativen Katastrophenmanagements. Goethe und die "Erfindung" des Erdbebens von Lissabon', in *Das Erdbeben von Lissabon und der Katastrophendiskurs im 18. Jahrhundert*, ed. Gerhard Lauer and Thorsten Unger (Göttingen: Wallstein, 2008), 162–72.

the lovers and, in turmoil, lynch them. Jeronimo and Josephe are killed neither by the state institutions nor by nature, but by the people's rage.

In Kleist's experimental set-up in Chile, contingency having led to the uproar in the church is ultimately congruent with the absolutist political death sentence. Readers, however, are well aware of the actual indeterminacies that carry the story. By masterfully overlaying a seventeenth-century catholic milieu with nineteenth-century ideas about contingency, the author depicts the openness of social processes. I argue that, like Kleist, geologists and seismologists started examining the uncertain environments of modernity. In so doing, they did not strive to manage the accidental by means of prediction or any form of disaster alleviation. For earth scientists, earthquakes turned out to be, as for Jeronimo and Josephe, fortunate moments. They offered a glimpse into the earth's interior. Geologists and seismologists sought to make creative use of the unpredictable but inescapable earthquakes. While Enlightenment earthquake debates had emphasised the weak foundation of all knowledge, seismologists in late nineteenth-century Switzerland and Germany participated optimistically in the scientific disciplining of the earth. As shown below, they tried to disclose the patterns of its features and behaviour even if there remained the open question of how exactly the knowledge they had begun to gather would begin to form a coherent whole or whether it would ever be useful in social spheres other than science.[35]

CONTINGENCY AWARENESS: DISCIPLINING PEOPLE

The history of seismology has it that institutionalisation began in the 1890s, when precision instruments and recording devices became so refined that scientists were able to observe the seismicity of the earth 'from any seismographic station whatsoever'.[36] Contemporaries, too, noted the break.[37] The Swiss physiologist, hydrologist and meteorologist François Alphonse Forel (1841–1912)

35. On the old idea of classifying and ordering earthquake-related observations see, for instance, Merian, *Über die in Basel wahrgenommenen Erdbeben*, 2; Volger, 'Untersuchungen über das letztjährige Erdbeben in Central-Europa', 85; Edmund von Mojsisovics, 'Mittheilungen der Erdbeben-Commission der kaiserlichen Akademie der Wissenschaften in Wien', *Sitzungsberichte der Kaiserlichen Akademie des Wissenschaften. Mathematisch-naturwissenschaftliche Klasse* **106** (V. Sitzung vom 11.2.1897): 20–59 (21); on the uncertainties regarding the results and uses of seismology see Georg Gerland, 'Über Verteilung, Einrichtung und Verbindung der Erdbebenstationen im Deutschen Reich', *A. Petermanns Mitteilungen aus Justus Perthes' Geographischer Anstalt* **48** (1902): 151–60 (159).

36. Dewey and Byerly, 'The Early History of Seismometry', 183; Schweitzer 2007; for the quote see Wiechert, 'Was wissen wir von der Erde unter uns?' 386.

37. Fernand de Montessus de Ballore, *La science séismologique. Les tremblements de terre* (Paris, 1907), 1; Sieberg, *Der Erdball*, 312; Alphonse Forel, in: Swiss National Archives Berne BAR E 88 154, Bern, 8. August 1908, Entwurf, Das eidgen. Department des Innern an den Bundesrat, 2–3: 'Seismology has evolved into a discipline in its own right over the last 15 years [...] This became possible only since [...] fine tremors and even distant earthquakes have been instrumentally registered.'

subscribed to this view when he rhapsodised: 'More has been learnt from the seismograph-tracer of Anglo-Japanese observers in two years than twenty centuries of European science had been able to show.'[38] Arguably, Forel admired instrument-based research because he himself was contributing to the macroseismic observation of his country. Being the co-creator of an earthquake intensity scale used internationally since the 1880s, the Rossi-Forel Scale, he knew the difficulties the Swiss project was struggling with all too well.[39] However, the Swiss earthquake observation case suggests, as does the Austrian earthquake committee modelled after the Swiss example,[40] that technoscientific advances in seismography do not fully explain the swift establishment of seismology around 1900. Alpine tectonics and, linked to it, macroseismology also played their part in the development of the discipline.

Macroseismology gained momentum in the late nineteenth century because it became part of the flourishing mountain science crystallising around the Alps as both a scientific object and a territory for fieldwork in different disciplines.[41] Alpine geologists suggested that the causes of seismic activities were mainly related to tectonic mechanisms, the dynamic forces operating beneath the earth's crust and piling up mountains. Tectonic research or, as it was also called, research on the 'distortions' or 'displacements'[42] of the earth's crust complemented geological approaches with roots in natural history such as mineralogy, physical geography, and stratigraphy. From the beginning, the study of the physical forces deployed in the upper crust of the earth entailed a global perspective that was difficult to ignore. The idea that geology ultimately worked towards a structural synthesis was a commonly held conviction among scholars of the nineteenth century.[43] At

38. *Transactions of the Seismological Society of Japan* Vol. 11, 165.

39. On the use of the Rossi-Forel scale in Imperial Germany see, for instance, Bundesarchiv Berlin R 901/37908 Anleitung zum Beobachten von Erdbeben (no year, circa 1906), 4. The scale was based on phenomenological observation which depended on the individual observer, his distance from the epicentre of a quake, and on the local environment. The Rossi-Forel Scale would also be part of the questionnaire the State Earthquake Investigation Commission distributed to Californians after the San Francisco earthquake of April 18, 1906, Andrew Lawson, ed. *Preliminary report of the State Earthquake Investigation Commission* (Berkelewy, 1906), n. p. 18.

40. Charles Davison, *The Founders of Seismology* (Cambridge: Cambridge University Press, 1927), 138ff.

41. On mountain science see Charlotte Bigg et al. 'Introduction: The Laboratory of Nature: Mountains as Objects and Instruments of Sciences', *Science in Context*, **22** (3/2009): 311–21.

42. Bernhard Studer, 'Brief vom 4. Oktober 1836', in *Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde* (1836), 694–709 (696); the notion 'tectonics' was first introduced by Carl Friedrich Naumann, *Lehrbuch der Geognosie*, 3 Vol. (Leipzig: Engelmann, 1850), 899.

43. Mott Greene, *Geology in the Nineteenth Century. Changing Views of a Changing World*, Cornell History of Science Series (Ithaca, London: Cornell University Press, 1982), 88 and 156; Sandra Herbert, *Charles Darwin, Geologist* (Ithaca, London: Cornell University Press, 2005), 80 and 85.

the same time, however, tectonic questions were judged premature because any attempt at answering them only pointed to the many theoretical uncertainties and empirical lacunae in the study of the earth.[44] As a rule, tectonic theorising was put aside for the sake of gathering stratigraphic evidence through meticulous fieldwork and only resurged in the 1870s with Eduard Suess (1831–1914) from Vienna and his essay on the *Origin of the Alps* (1875); and Albert Heim's voluminous *Studies on the Mechanism of mountain building* (1878). Suess and Heim held that the Alps had been piled up due to tangential forces. Challenging the older opinion that mountain chains were uplifted by vertical forces, the two scientists initiated the epoch of modern tectonics.[45] To them, earthquakes fitted well into the new picture: 'Earthquakes are the expression of the continuing processes of mountain building through lateral pressure [*Gebirgsstauung*].'[46] Suess argued that 'great fracture lines' evidencing tectonic dislocations 'have an effect on the distribution of earthquakes'.[47] They both maintained that tectonic or dislocation earthquakes were the most important class of earthquakes, much more common than tremors due to the collapse of underground caves or volcanic earthquakes, the two geological causes hitherto put forward. The idea soon became a standard.[48] In order to register ongoing movements along tectonic fault lines, they called for permanent and simultaneous macroseismic observation.

44. The process-oriented global perspective in tectonics which conceived of the earth's crust as a structural system differed, in its logic, from the idea of universality which guided the classificatory endeavours of stratigraphy. The latter used and refined a taxonomy held to be general, i.e. globally applicable, as a means for describing the *local* order of rock strata and correlating the stratigraphic evidence of different sites. Tectonic research, in turn, aimed at observing *wide-ranging* phenomena: dynamic processes extending well beyond the regional scope. In targeting the causal dynamics, the tectonic interest of research was also at variance with the global inventory of the geographic features of the earth's crust created by physical geographers.

45. Greene, *Geology in the Nineteenth Century*, 147–53 and 194–5; Andrea Westermann, 'Inherited Territories. The Glarus Alps, Knowledge Validation, and the Genealogical Organization of 19th-century Swiss Alpine Geognosy', *Science in Context* **22** (3/2009): 439–61.

46. Albert Heim, *Die Erdbeben und deren Beobachtung. Auf Veranlassung der Erdbeben-Commission der Schweizerischen Naturforschenden Gesellschaft* (Zürich: Druck von Zürcher und Furrer, 1879), 19; Albert Heim, *Das ostschweizerische Erdbeben vom 2. Mai 1877. Bericht, den Einsendern von Beobachtungsnotizen abgestattet* (o. A. 1877), 16.

47. Eduard Suess, 'Die Erdbeben Nieder-Österreichs', *Denkschr. k. Akad. Wiss. mathem.-naturwiss. Cl.* **33** (1874): 61–98 (61); also Rudolf Hoernes, 'Erdbeben-Studien', *Jb. k.k. Geol. Reichsanst.* **28** (1878): 387–448; Albert Heim, *Das Verhältnis der Erdbeben zu den Gebirgen* (Zürich: 1879); Heim, *Die Erdbeben und deren Beobachtung*; Albert Heim, 'Über die Untersuchung der Erdbeben und deren bisherige Resultate', *Vierteljahrsschrift der Naturforschenden Gesellschaft in Zürich* **24** (1879): 311–16 (313); referring to Suess and Hoernes; on the early Austrian research on tectonic earthquakes see Deborah Coen, 'Fault Lines and Borderlands: Earthquake Spotting in Imperial Austria', paper presented at the workshop 'Witness to Disaster: Comparative Histories of Earthquake Science and Response', 29–30 October, 2009, Barnard College, Columbia University New York.

48. 'Erdbeben' in: *Meyers Konversationslexikon,* 4th ed., Leipzig and Wien 1885–1892, 737.

Earthquake spotting had been pursued before. Early compilers of historical earthquake catalogues had drawn on written sources of all kinds from which they had sought to select the relevant and truly scientific data.[49] As earthquake studies developed, earthquake researchers relied more on fieldwork and on reports drawn up by individuals who had themselves experienced the earthquake in question. An early example comes from Switzerland in 1855, when the German naturalist Georg Heinrich Otto Volger (1822–1897) seized the opportunity of a strong earthquake in the Valais canton of Switzerland to collect data on-site. Moreover, he 'urged the educated people to immediately jot down their observations and send them in'.[50] The work of the Swiss earthquake committee differed from earlier efforts, including Volger's, in that it was a future-oriented network aiming to generate, process and store data in a controlled and standardised way or, as the Austrian committee put it, to create 'a network of permanent observers'.[51] In this respect, the Swiss Alpine region accounted for a perfect – moderate – climate of observation: earthquakes occurred regularly but did not usually do any severe damage.[52] This moderate seismicity, the scientists noted, facilitated the enrolment of Swiss citizens in that it spurred the public interest. 'Nature itself arranged for an ongoing interest because the first years

49. Karl Ernst Adolf von Hoff, *Geschichte der durch Überlieferung nachgewiesenen natürlichen Veränderungen der Erdoberfläche. Ein Versuch. II. Theil Geschichte der Vulcane und Erdbeben* (Gotha: Perthes, 1824), IX; Peter N. C. Egen, 'Über das Erdbeben in den Rhein- und Niederlanden vom 23. Februar 1828', *Annalen der Physik und Chemie* **13** (1828): 153–63, 176–9, plate (153). These catalogues have become a source of historical seismology, Monika Gisler et al., 'The Valais Earthquake of December 9, 1755', *Eclogae geol. Helv.* **97** (2004): 411–22 (412–14).

50. Otto Volger, 'Untersuchungen über das jüngste grosse Erdbeben in Central-Europa', *Mittheilungen aus Justus Perthes' geographischer Anstalt über wichtige neue Erforschungen auf dem Gesamtgebiete der Geographie, von A. Petermann* **1** (1855), 232; on Volger see Monika Gisler et al. 'The 1855 Visp (Switzerland) Earthquake: A Milestone in Macroseismic Methodology?' in *Historical Seismology: Interdisciplinary Studies of Past and Recent Earthquakes*, ed. Julien Fréchet et al., Modern Approaches in Solid Earth Sciences 2 (Berlin, Heidelberg: Springer, 2008), 225–41. An earlier project of field data collection and on-site drawing was commissioned by the Neapolitan Royal Academy of Sciences and Letter on the occasion of the Calabrian earthquake of 1783, see Susanne B. Keller, 'Sections and Views: Visual Representation in Eighteenth-century Earthquake Studies', *British Journal for the History of Science* **31** (1998): 129–59 (150–9); field research and press calls were also the means chosen by Peter Egen in 1828 for studying an earthquake in the Rhineland and the Netherlands, see Egen, 'Über das Erdbeben in den Rhein- und Niederlanden vom 23. Februar 1828', 153; Robert Mallet did reconnaissance work on the Neapolitan earthquake of 1857, Dennis R. Dean, 'Robert Mallet and the Founding of Seismology', *Annals of Science* **48** (1991): 39–67, (58–63).

51. Mojsisovics, 'Mittheilungen der Erdbeben-Commission', 21.

52. Swiss earthquakes had long since gained attention: see the reference list with nearly 300 articles, published between 1790 and 1900, in the *Bibliographie géologique de la Suisse* (Mat. pour la carte géol. de la Suisse, XXIX livraison, 2eme partie, Bern: Francke, 1908), 770–90.

after the organisation [of the committee] were a period rich in quakes'.[53] The geographical extension of a felt earthquake could only be determined through collaborative observation. The members of the Swiss and Austrian committees relied on the 'many friends of science' or 'friends of the Alps'.[54] They decided to divide their countries up into regions and build 'local networks by bringing in qualified personalities'.[55] Ideally, 'the net was cast over the topographical map' and later adapted to the regional circumstances, in case the meshes and knots drawn at the desk pointed to districts where no such persons lived.[56] The Swiss committee addressed itself to societies of natural history (organized on a cantonal level), members of the Swiss Alpine Club who were considered to be equally scientific-minded (in fact, there was no small overlapping membership), telegraph stations, members of the meteorological observation network[57] and the newspapers. The referee for Lower Austria chose 'teachers or headmasters, in the first place, but also physicians, pharmacists, pastors, postmasters, estate managers, forest officers, in short, persons, whose job makes them meet many people'.[58] From 1879, the Swiss committee distributed a two-page 'instruction for earthquake observation without special instruments'. Proclaiming that 'the one who knows what he is supposed to notice pays attention to many things overlooked by others', it explained the necessity of sustaining rationality in the face of earthquakes and adopting a scientific observer's attitude.[59] It was important to keep a clear mind since accurate observation was based on strict self-control and discipline: 'Fantasy tends to overgrow thinking' when 'the seemingly solid ground of the existence lurches ... just in the few moments when observation is due.'[60]

Heim and others assumed that macroseismic data collection helped test and reveal the tectonic structure of the Alpine regions. At the same time, macroseismic observation was meant to raise awareness amongst the general public about certain conditions of modern life. People were invited to attune their

53. Albert Riggenbach, *Die Organisation der Erdbebenbeobachtungen in der Schweiz. Beilage A IX des Berichts der I. Internationalen seismologischen Konferenz.* (Off Print, 1903), 166.

54. Heim, *Das Verhältnis der Erdbeben zu den Gebirgen*, 6; Heim, *Die Erdbeben und deren Beobachtung*, 6; Riggenbach, *Die Organisation der Erdbebenbeobachtungen in der Schweiz.*

55. Mojsisovics, 'Mittheilungen der Erdbeben-Commission', 22; Heim, *Die Erdbeben und deren Beobachtung*, 30; A. Forster, 'Über Erdbeben', *Jahresbericht der geographischen Gesellschaft von Bern* **9** (1888–1889), 71–81 (72–3).

56. Mojsisovics, 'Mittheilungen der Erdbeben-Commission', 24.

57. On the Swiss meteorological network see Michael Bürgi, 'Hinlänglich gebildet und republikanisch gesinnt – Meteorologie im bürgerlichen Verein', in *Lokale Naturen. 150 Jahre Thurgauische Naturforschende Gesellschaft*, ed. Michael Bürgi and Daniel Speich (Weinfelden: Wolfau, 2004), 37–62.

58. Mojsisovics, 'Mittheilungen der Erdbeben-Commission', 24.

59. Heim, *Die Erdbeben und deren Beobachtung*, 23.

60. Heim, *Das ostschweizerische Erdbeben vom 2. Mai 1877*, 1.

minds to the relative normality of a pulsing earth 'animated by seismic nerves'[61] and acknowledge what the new perspective implied: from a global view, local exceptions and sudden accidental events might be part of the normal course of things. 'Not a single day goes by without twitches running through large parts of the Earth's crust. We call them earthquakes', Heim explained in 1879, when aiming to illustrate their frequency to the Swiss public.[62] With hindsight, he reminded his colleagues in 1909: 'the statistical analysis [of macroseismic observations] taught us something new and important: the enormous *frequency*, the *ordinariness* of earthquakes. 10 to 20 felt earthquakes occur every day, microseismic waves are registered every hour.'[63] The Swiss earthquake committee also demonstrated that society could benefit even from nature's uncertainties if only enough individuals tuned themselves to the industrial and technoscientific 'values of precision'[64] and practised a division of labour.

However, the cooperation of the Swiss public was not easily obtained. Even if shocks had been apparent to their senses at a given moment, people had to decide whether they could actually spare the time to write down their observations. As one woman put it, between a dying father and an ill sister, it was hard to pay attention to the abstractions science was interested in. Many of the collaborators reserved their right to anonymity.[65] People answered in larger numbers once they were encouraged to believe that there was good reason for having recorded something noteworthy. After special requests, for instance when asked about observations made in relation to a severe earthquake in Messina and Calabria (Italy) in December 1908, more letters than usual poured in. The writers traced vibrations back to earthquakes 'somewhere', 'however remote they might be'.[66] Also, they were more willing to submit their observations once they had gathered collective evidence from their family and their neighbours. In these cases, the description and interpretation of earthquakes became the subject

61. Forel 1901 quoted in *Botschaft des Bundesrats an die Bundesversammlung betreffend die Erweiterung der eidgenössischen meteorologischen Zentralanstalt*, 7.2.1913, 263.

62. Heim, *Das Verhältnis der Erdbeben zu den Gebirgen*, 6. John Milne found, between 1892 and 1904, records 'for at least 750 world-shaking earthquakes', Milne, 'Recent Advances in Seismology', 372.

63. Albert Heim, 'Einiges über den Stand der Erdbebenforschung. Conférence VI', in : *Comptes-rendus des séances de la troisième réunion de la Commission Permanente de l'Association Internationale des Sismologie réunie à Zermatt du 30 août au 2 septembre 1909*, ed. R. de Kövesligethy (Budapest: Hornyansky, 1909), 1–5 (1, emphasis in the original).

64. M. Norton Wise, ed. *The Values of Precision* (Princeton: Princeton University Press, 1995).

65. Archives ETH, papers Hans Schardt, Hs 389:1077.3; Hs 389:1077.15.

66. Archives ETH, papers Hans Schardt, Hs 389:1076.9, 1-2: 'Pour répondre à votre demande insérée dans la Flle d'avis de ce jour, je veux vous dire, que cette même nuit du 28 Dec. bre vers le matin (je n'ai pas regardé l'heure), j'ai ressenti, non pas des secousses, mais des vibrations assez intenses pour me faire supposer qu'un violent tremblement de terre devait se produire quelque part. J'ajoute que bien souvent déjà, j'ai eu l'occasion de constater qu'un tremblement de terre (si fort éloigné que puisse être) me donnait cette sensation des vibrations.'

of daily conversations.[67] Between 1880 and 1909, the Swiss earthquake committee processed about 7000 reports. Each of the seven members of the committee collected information from the region assigned to him and was expected to collate the findings for further analysis in the annual reports. Between seven and 174 shocks per year were registered, adding up to 998 shocks for the period in question. The committee took pains to identify the shocks caused by the same earthquake event. Grouped together, they accounted for 231 felt earthquakes over the thirty years.[68]

Albert Heim's best source for the canton Grisons, for instance, was the historian and schoolteacher Dr. Christian Gregor Brügger (1833–1899). Brügger was very skilled at enrolling people in scientific collaboration. He had cast a reliable 'net of observation' over Grisons. Though this canton was covered mostly by wild mountain ranges, the network was much 'denser' than the reporting systems of other cantons, Heim noted approvingly.[69] The committee appreciated citizens like Brügger because the quality of data depended mainly on the zeal and the culture of gathering.[70] The collaborators were requested to report on the intensity of the shocks and the direction of the movements. They were asked to state as exactly as possible the time of commencement and the duration of each shock. Uncertain observations should be marked as such. Failure to make any observations at all was a result that should not be withheld. Since the shocks were reflected on their way through different rock strata, it was difficult to determine where they had originated, even if an observer indicated a certain direction. Moreover, the tremor could be perceived differently by someone sitting in a chair on the second floor of a building compared with someone walking outdoors. By analysing a large number of indicated directions, however, the committee hoped to overcome these limitations. They were confident that the sheer mass of observations 'would factor out local errors. The individual observer is unable to do so.'[71] And yet, it was clear from the outset that the macroseismic data collected was deficient in many ways, which made it difficult to generalise from. To add one more source of uncertainty: a huge distortion stemmed from the patterns of attention that people were subject to in their daily routines. Early in the morning and late at night, during what Heim and others called 'times of quietude', people were more attentive to shock waves than during working hours. Thus, the annual reports suggested, erroneously, that earthquakes tended to happen at night. By relying on the observations of an

67. Archives ETH, papers Hans Schardt, Hs 389:1077.9; 389:1077.4.

68. J. Früh, *Über die 30-jährige Tätigkeit der schweizerischen Erdbebenkommission* (Off Print, 1911), 5–7.

69. Albert Heim, *Die schweizerischen Erdbeben vom November 1879 bis Ende 1880. Nach den von der schweiz. Erdbebenkommission gesammelten Berichten* (Bern: Haller, 1881), 7–8; it is an open question as yet why Brügger was so successful in reaching the public.

70. Früh, *Über die 30-jährige Tätigkeit der schweizerischen Erdbebenkommission*, 7.

71. Heim, *Das ostschweizerische Erdbeben vom 2. Mai 1877*, 3.

'unevenly sensitive instrument of measurement – man – the statistics collected so far were imprecise', the committee concluded.[72]

The most important organisational task was to get the time records right.[73] Railways and other institutions had forced people to keep time to the minute but they did not yet pay any particular attention to the meaning of the second: 'Of course, your normal watch will not do it. It is easy enough, though, to read off the time to the fraction of a minute. Then hurry to the nearest telegraph station or astronomical clock in order to compare your watch with the exact time they display and jot down the difference', Heim proposed.[74] Notable exceptions, praised in the annual reports, were the centres of Swiss clock making. Their observations were taken seriously because the geologists felt that time and the idea of precision were valued differently in these cities and regions: when the committee had to average the differing times given, it thought it best to give more weight to the data stemming from Geneva or the canton of Jura. In the eyes of the committee, socially trustworthy and technically inclined persons such as professors of physics, directors of telegraph stations, or clockmakers submitted 'the best and most diligently controlled time designations'. From early on, the Swiss postal and telegraphic services were asked to help measure the exact time and provide swift communication. In the 1910s, relations with telegraph stations were put on new grounds 'due to the introduction of the telephonically transmitted 11 a.m. time signal ... About 15 of our observers get the time signal daily and for free. Telephone calls to Zurich and Lausanne for the purpose of comparing the time are not charged.'[75]

Surprisingly enough, the many doubts did not generate a loss of interest in the project. On the contrary, geologists shared the conviction that building a macroseismic 'archive' or 'data collection' was important anyway.[76] They were optimistic that the large amount of gathered data would eventually cause the seismic regions to 'map themselves with sufficient accuracy', as Montessus de Ballore put it in his article 'Seismic Switzerland'.[77] From a long-term perspective, a 'communitarian objectivity'[78] sought to overcome individual flaws, situational

72. A. Forster, *Die schweizerischen Erdbeben im Jahre 1882. Zusammengestellt nach den von der schweiz. Erdbebenkommission gesammelten Berichten* (Bern: Stämpfli, 1883), 14; François Alphonse Forel, 'Les tremblements de terre étudiés par la commission sismologique suisse pendant les années 1882 et 1883', *Archives des sciences physiques et naturelles* **13** (1885): 377–96 (395).

73. Heim, *Die Erdbeben und deren Beobachtung*, 17.

74. Ibid. 24.

75. Bundesarchiv Bern E88 154, Bericht über den Erdbebendienst 1916, Abs. 2, 7.

76. Riggenbach, *Die Organisation der Erdbebenbeobachtungen in der Schweiz*, 166.

77. Montessus de Ballore, 'La Suisse sismique', 35.

78. Lorraine Daston, 'Scientific Objectivity with and without Words', in: *Little Tools of Knowledge. Historical Essays on Academic and Bureaucratic Practices. Social History, Popular Culture, and Politics in Germany*, ed. Peter Becker and William Clark (Ann Arbor: University of Michigan Press, 2001), 259–84 (262).

particularities, parochialism and the difference between professional scientists and lay collaborators. Moreover, the longstanding hope that, from the safely stored data, 'some patterns might emerge' or that they 'might lead to the formulation of some guiding theories' in the not too distant future was fostered by the new insights gained in Alpine and global tectonics.[79] Montessus de Ballore's personal files, for instance, went on to document 170,000 events worldwide.[80] Taken together in 1911, the archival records showed two earthquake belts. One was the Alpine–Caucasian–Himalayan zone; the other was the Circum-Pacific zone (see fig. 1).

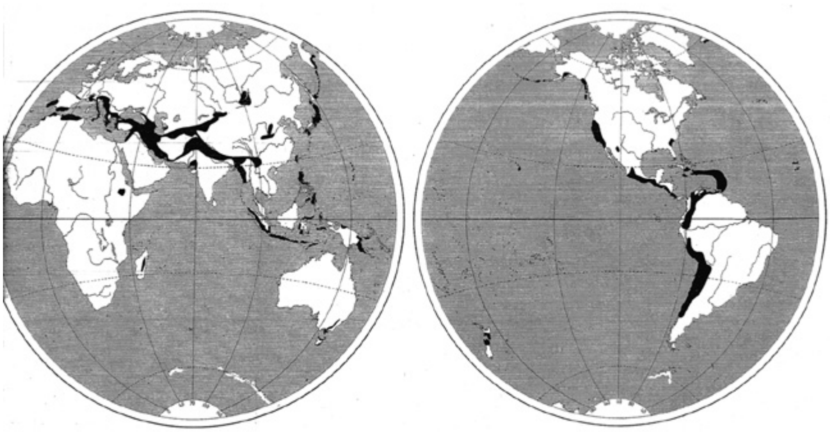

FIGURE 1. Visualising the global earthquake belts.
The caption of the map reads 'Seismic regions. Old World. New World', in Fernand de Montessus de Ballore, *La Sismologie moderne* (Paris 1911), inserted map.

A NEW IMAGE OF THE INNER EARTH

By the end of the nineteenth century, Swiss naturalist Elie de Bertrand's remark in his *Historical and Physical Treatise of Earthquakes* of 1766 – 'we know the surface of the earth through travelling, its interior through simple conjectures'[81] – still largely held true. For most of the century, geologists and geophysicists had predicted that the study of earthquakes offered a means of knowing the inner earth. Peter Merian (1795–1883), a Swiss geognosist, had speculated about the value of earthquakes for 'a theory of the formation of the earth's surface'

79. David Oldroyd et al. 'The Study of Earthquakes in the Hundred Years Following the Lisbon Earthquake of 1755', *Earth Sciences History* **26** (2/2007): 321–70 (344).

80. They are now stored at the Archives Nationales in Paris.

81. Cited after Gisler, *Göttliche Natur?* 166.

as early as 1834.[82] The *Naval Manual of Scientific Enquiry*, Britain's official guide to scientific travel, had explained that the 'observations of the facts of earthquakes and the establishment of their theory' had their immediate and most important applications in the 'discovery of the nature of the deep interior of our planet, and of the reactions of the interior upon the exterior'.[83] The conviction that earthquakes were one of the rare opportunities where data about the inner structure of the earth became available and the fact that this happened at a determined time and under particular conditions suggested to contemporaries likening the situation to an experiment.

Occasionally, in the eighteenth and early nineteenth centuries, the idea of experimentation, the artificial set-up to test a scientific hypothesis by inducing externally controlled changes in the system and measuring the observable effects, had been dissociated from the contained space of the laboratory. Authors such as Auguste Comte, John Stuart Mill or Adolphe Quetelet had used the term experiment with respect to natural disasters like earthquakes or floods. It is important to note, however, that they considered society to be the object of experimentation.[84] By the end of the nineteenth century, in contrast, earthquakes were seen as experiments in the scale of 1:1, with the globe being the object under study. Geologists considered earthquakes to be a recurring occasion to observe tectonic dislocation patterns across the earth's surface. With the advent of self-registering devices sensitive to microseismic waves around 1900, they declared 'that the new tectonic theory had been experimentally confirmed by seismology around the globe'.[85] It was a quasi-experimental situation, to be sure, since the scientists' means of manipulation and control were limited. However, the networks of macroseismic or microseismic observation made the earth part of a consciously devised setting. In 1904, Emil Wiechert chose the language of experiment. Whereas scientific experimenters gained knowledge about nature by manipulating the experimental system representing it, instrument-based seismology captured, he claimed, nature's work in its actual scope.[86] Seismographs did not depend on earthquakes happening nearby, more or less often but without

82. Merian, *Über die in Basel wahrgenommenen Erdbeben*, 1; also Volger, 'Untersuchungen über das letztjährige Erdbeben in Central-Europa', 85.

83. Robert Mallet, 'Earthquake Phenomena', in *A Manual of Scientific Enquiry; Prepared for the Use of Officers in Her Majesty's Navy and Travellers in General*, ed. John Herschel (London: Murray, 1859), 325–63 (325). Together with John Milne, Robert Mallet advanced the science of seismology in Victorian Britain; Davison, *The Founders of Seismology*, 65–86 and 177–202; Dean, 'Robert Mallet and the Founding of Seismology'; Wiechert, 'Die Erdbebenforschung, ihre Hilfsmittel und ihre Resultate für die Geophysik', 36–7; A. Sieberg, 'Erdbeben-Geologie', in *Lehrbuch der Geophysik*, ed. Beno Gutenberg (Berlin: Borntraeger, 1929), 163–219 (163).

84. Trudy Dehue, 'Social Experiments, History of', *Encyclopedia of Social Measurement* (London, Amsterdam, New York: Academic Press, 2005), 509–16 (510).

85. Montessus de Ballore, *La science séismologique*, 26–7.

86. Wiechert, 'Entwurf einer Denkschrift über seismologische Beobachtungen in den deutschen Kolonien', in *Verhandlungen der Zweiten Internationalen Seismologischen Konferenz*,

any chance of predictability. They allowed earthquake research to be undertaken on a regular basis, generating a constant flow of data regarding the seismicity of the earth.[87] The propagation of seismic waves in the interior of the earth was disclosed by sensitive pendulums capable of amplifying the microscopic events in such a way that a registering device would visualise the shocks as a curve. Until 1900, the central mechanism in seismographs was a hanging pendulum to which a stylus was attached. A shock displaced the fulcrum of the pendulum and caused the mass of the inert pendulum to oscillate. Long periods of oscillation were needed to record major earthquake shocks while neglecting minor reverberations. With a static magnification of over 500 and an eigen-oscillation of twelve to fifteen seconds, Wiechert's inverted pendulum of 1903 was ideally suited for recording tremors from distant earthquakes coming in quick succession. By 1905, nine observatories around the world had an inverted pendulum based on Wiechert's design.[88] Making microseismic waves visible was an elaborate process and justified the shift in the scientific perception of earthquakes from natural catastrophes to generators of data. 'To the man in the street the question whether a thing is large or small is all important. To the scientific man it matters not at all', the president of the International Seismological Association was eager to emphasise.[89]

Gerland in Strasbourg claimed that, just as for research in astronomy, geodesy, meteorology and hydrography, only 'a never-ending dataflow' and 'ubiquitous observations' would allow for an understanding of both local and world-disturbing earthquakes.[90] At the seismological stations equipped with delicate seismographs, a stream of data was arriving, originating in or passing through and beneath hitherto unreachable spots of the earth's crust such as oceans, deserts and high mountain ranges.[91] This data helped piece together a new image of the globe (see fig. 2). The seismological data was to be filed in national archives and forwarded to the International Seismological Association in Strasbourg for further processing and storage.[92] In the nineteenth century, imperial archives and

Beiträge zur Geophysik. Ergänzungsband 2, ed. Emil Rudolph (Leipzig, 1904), 313–18 (313).

87. Montessus de Ballore, *La science séismologique*, 7.

88. Pyenson, *Cultural Imperialism and Exact Sciences*, 36–7; Dewey and Byerly, 'The Early History of Seismometry'.

89. R. de Köveslighty, ed. *Comptes-rendus des séances de la quatrième conférence de la commission permanente et de la deuxième assemblée générale de l'Association Internationale de Sismologie réunies à Manchester du 18 au 21 juillet 1911* (Budapest: Hornyansky, 1912), 8.

90. Georg Gerland, 'Über Verteilung, Einrichtung und Verbindung der Erdbebenstationen im Deutschen Reich', *Beiträge zu Geophysik. Zeitschrift für physikalische Erdkunde* **6** (1903): 464–80 (467).

91. Wiechert, 'Was wissen wir von der Erde unter uns?' 386; Rebeur-Paschwitz, ‚Vorschläge zur Errichtung eines internationalen Systems von Erdbeben-Stationen', 773.

92. Gerland, 'Die Kaiserl. Hauptstation für Erdbebenforschung in Strassburg und die moderne Seismologie', 442–3; Georg Gerland, ‚Die erste internationale Erdbebenkonferenz zu

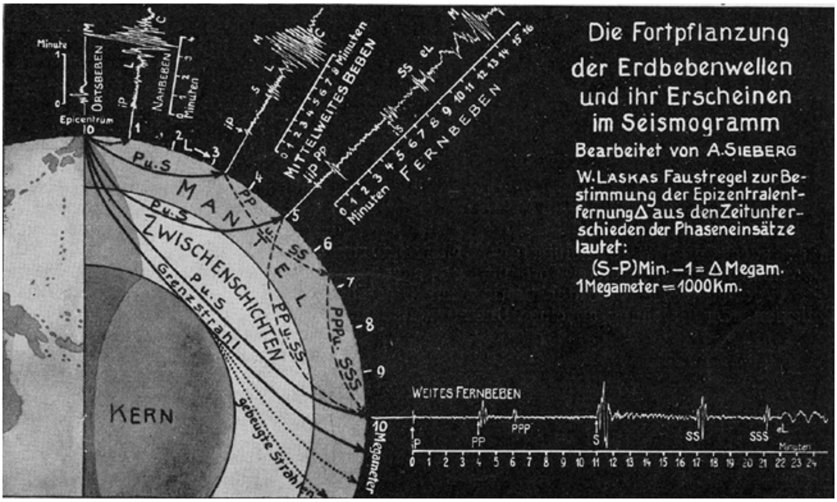

FIGURE 2. Earthquake waves and the new image of the globe, in August Sieberg, *Geologische Einführung in die Geophysik* (Jena, 1927), 285.

international scientific archives or central bureaus embodied 'the utopian space of comprehensive knowledge'.[93] Both types of archives dealt with spaces difficult or impossible to travel to and, in any case, impossible to occupy permanently: remote colonial territories, the deep sea, the atmosphere, the inner earth. In the scientific archival projects the ideal of Humboldtian science converged with political power and colonial aspirations. More often than not, this knowledge was waiting to be produced: microseismologists believed, like their colleagues collecting macroseismic information, that scientific progress would, in the near future, provide the necessary means to turn the overwhelming amount of data into coherent theories and explanations.

If the microseismic records represented continuity, they also aspired, due to the self-registering method of data collection, to universality. Across the different sciences of the time, the self-inscribing graphs were hailed as the true language of nature and the universal language of science.[94] At least in theory, and when

Straßburg', *A. Petermanns Mittheilungen aus Justus Perthes' Geographischer Anstalt* **47** (1901): 115–19 (116).

93. Thomas Richards, *The Imperial Archive. Knowledge and the Fantasy of Empire* (London, New York: Verso, 1993), 11. On the conquest of the atmosphere via data collection see, for instance, Sabine Höhler, *Luftfahrtforschung und Luftfahrtmythos. Wissenschaftliche Ballonfahrt in Deutschland, 1880–1910*, Campus Forschung 792 (Frankfurt a. M.: Campus, 2002), 283–303; on the history of ocean profiling see Sabine Höhler, 'Depth Records and Ocean Volumes. Ocean Profiling by Sounding Technology, 1850–1930', *History and Technology* **18** (2/2002): 119–54..

94. Daston, 'Scientific Objectivity With and Without Words', 276–9; Robert Brain, 'Representation on the Line: Graphic Recording Instruments and Scientific Modernism',

interpreted in the correct way: international earthquake research was confronted with the difficulty of analysing seismograms stemming from stations with different instrumentation and work cultures.[95] For many years, the International Seismological Association failed to sort out the problems of comparison and standardisation.[96] 'The situation is such', the director of the Potsdam Institute of Geodesy explained in 1909, 'that many important circles, especially in England and Russia, have lost confidence in the central bureau. An immense and growing mass of observational data is sent to Strasbourg, but nobody is able to process it for further scientific interpretation.'[97]

Instrument-based seismology linked different sites and environments. It did so not only because the epicentre of an earthquake was calculated from the data registered by at least three seismographs installed at appropriate distances[98] but also because seismograms disclosed regular patterns in seemingly random earthquake movements. In Göttingen, Wiechert had based his research on the idea that a particular version of wave theory could be applied to seismic waves.[99] He repeatedly observed that the seismographs of two different earthquake events displayed a striking similarity. He concluded 'that the characteristic development of shock movements must be independent of the events that had caused them'.[100] What should or could be expected from the seismograms? They had to be 'legible', Wiechert stated, meaning that they had to tell the scientist something about the kinds of waves arriving at the station.[101] As long as an observer did not formulate theoretical assumptions and hypotheses about the waves and their spread, he could hardly understand what exactly his instruments had revealed. Seismographs, to mention only one of the more obvious problems, reacted

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in *From Energy to Information. Representation in Science, Technology, Art and Literature*, eds. Bruce Clarke and Linda Darymple Henderson (Palo Alto: Stanford University Press, 2002), 155–77 (156–7).

95. On the procedure see the introduction by Beno Gutenberg, *Die mitteleuropäischen Beben vom 16. November 1911 und vom 20. Juli 1913. I. Bearbeitung der instrumentellen Aufzeichnungen*. Veröffentlichungen des Zentralbureaus der internationalen seismologischen Assoziation (Würzburg: Stürtz, 1915), III–IV.

96. Marielle Cremer, *Seismik zu Beginn des 20. Jahrhunderts: Internationalität und Disziplinbildung*, Berliner Beiträge zur Geschichte der Naturwissenschaften und der Technik, Bd. 28 (Berlin: ERS –Verlag, 2001).

97. Cited after Cremer, *Seismik zu Beginn des 20. Jahrhunderts*, 151.

98. F. Pockels, 'Die Ergebnisse der neueren Erdbebenforschung in bezug auf die physikalische Beschaffenheit des Erdinnern', *Geologische Rundschau* **1** (6/1910): 249–68 (253).

99. Renate Tobies, 'The Development of Göttingen into the Prussian Centre of Mathematics and the Exact Sciences', in: *Göttingen and the Development of the Natural Sciences*, ed. Nicolaas Rupke (Göttingen: Wallstein, 2002), 116–42 (134); Wilfried Schröder, 'Emil Wiechert and the Foundation of Geophysics', *Archives Internationales d'Histoire des Sciences* **38** (1988): 277–88 (277).

100. Emil Wiechert, 'Theorie des automatischen Seismographen', *Abhandlungen der königlichen Gesellschaft der Wissenschaften zu Göttingen. Mathematisch-physikalische Klasse* N.F. **2** (1/1903): 3–125 (5).

101. Ibid. 4.

differently to waves according to the eigen-oscillation of the pendulum. Thus, a bigger disturbance of the seismograph did not necessarily correspond with a higher intensity of the quake. For the accuracy of the inscription, a damping device was desirable, Wiechert explained. The method that revolutionised earthquake studies was the propagation-time curves or *'Laufzeitkurven'*, worked out empirically over many years in Göttingen. The coordinate planes represented the propagation velocity of the waves: the curves plotted the distance from the epicentre against the time taken for a shock wave to travel that distance. Wiechert and his assistants found that the arrival times for a sequence of waves told more about the path the waves had travelled than about the intensity of the event. The geophysicists set out to describe the three groups of waves to be detected on seismograms (see fig. 1). The P (*primae*) waves were those compressional waves associated with the beginning of a tremor. The shear or S (*secundae*) waves represented the sharply defined beginning of a second phase of tremors. The main waves followed suit.[102] By analysing the shock waves from three big earthquakes, including the one that had hit California in 1906, Wiechert and his students confirmed that the first two wave groups had to make their way through the earth because they were much faster than the group of main waves supposedly travelling along the surface.[103] The shock waves furnished researchers with information about the physical properties of the earth's deep structure. The geophysicists in Göttingen came to recognise certain discontinuities (*'Unstetigkeitsflächen'*) in the propagation-time curves. At some points, the velocity abruptly increased due to, it was suggested, the higher density of the earth's composition. From this, they deduced that the earth's interior was divided into concentric shells with the smaller shells possessing greater propagation velocities. These findings confirmed the existing theories of an iron core and seemed to refute the idea of a liquid core.[104]

102. In a longitudinal or compressional wave, the particle displacement is parallel to the direction of wave propagation. The particles oscillate back and forth about their individual equilibrium positions as the wave passes by. In a transverse or shear wave, the particle displacement is perpendicular to the direction of wave propagation. The particles oscillate up and down about their individual equilibrium positions as the wave passes by. The main waves along the surface display, like water waves, both types of particle movement.

103. Emil Wiechert and Karl Zoeppritz, 'Über Erdbebenwellen', in *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse* (1907), 415–59.

104. Stephen Brush, *Nebulous Earth: the Origin of the Solar System and the Core of the Earth from Laplace to Jeffreys,* History of Modern Planetary Physics 1 (Cambridge, New York: Cambridge University Press, 1996), 141–202.

CONCLUSION

The seismological debates over the dynamics at work in and beneath the earth's crust disciplined the earth in the academic sense of the phrase. The scientific investigation of earthquakes gained momentum in the last third of the nineteenth century. From the 1880s, national and international observation networks were built to describe and analyse the seismicity of the earth. These many initiatives helped bring about a new synoptic image of the earth's physical features. Swiss and German seismologists tended to frame earthquakes, not in terms of a disastrous natural hazard, but in terms of a contingent 'modern' everyday occurrence. They emphasised their being a source of scientifically useful information. Microseismologists merged the contingencies of earthquakes with the 'seismicity of the whole earth' and were thus able to highlight the productive frequency of seismic wave propagation resulting in a constant stream of data. Macroseismologists sought to meet the contingencies of felt earthquake events by recruiting future eyewitnesses and instructing them to adopt and sustain fairly standardised rules of observation and reporting.

From the period in history explored here, spanning the years from the 1880s to the 1920s, the globe or the earth (*'Erdball'*, *'Gesammterde'*) emerged as a relevant point of reference for geophysical and geological research. The patterns which became manifest in the growing collections of seismograms did not show regularities in the temporal occurrence and magnitude of earthquakes but pointed to the multi-layered inner structure of the earth. Also, the global tectonic structure of the earth's crust began to take shape. The new images of the earth contributed to the idea of globality that, in its social and political sense, conveyed the possibility of scaling up collective action and taking action across political boundaries.