ANTHROPOCENE

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From the perspective of the history of science, the origin of the Anthropocene appears to be established with unusual precision. In 2000, Nobel laureate geochemist Paul Crutzen proposed that the planet had entered the Anthropocene, a new geologic epoch in which humans had become the primary driver of global environmental change. This definition should be easy to grasp for a generation that came of age during a period when anthropogenic global warming dominated environmental politics. The Anthropocene extends the primacy of anthropogenic change from the climate system to nearly every other planetary process: the cycling of life-sustaining nutrients; the adaptation, distribution, and extinction of species; the chemistry of the oceans; the erosion of mountains; the flow of freshwater; and so on. The human footprint covers the whole Earth. Like a giant balancing on the globe, each step accelerates the rate of change, pushing the planet out of the stable conditions of the Holocene Epoch that characterized the 11,700 years since the last glacial period and into a turbulent unknown with “no analog” in the planet’s 4.5 billion-year history. It is an open question how much longer humanity can keep up.

For its advocates, the Anthropocene signifies more than a catastrophic regime shift in planetary history. It also represents a paradigm shift in how we know global change from environmental science to Earth System science. Explaining the rise the Anthropocene, therefore, requires grappling with claims of both ontological and epistemological rupture; that is, we must explore the entangled histories of the Earth and its observers.

Since 2010, the rate of publication about the Anthropocene has mirrored the exponential increase in human impacts. The concept’s success reflected its spread from the Earth sciences to the social sciences and humanities. Since humans were conceived as the lead actor in this epic drama, humanists and social scientists felt empowered to join the conversation on relatively even ground with the Earth System scientists who identified the epoch and the geologists who debated its formalization as a unit of geological time. This convergence of interests made the Anthropocene the object of hotly contested interdisciplinary debates on problems of temporal and spatial scale, rupture and continuity, the human-nature relationship, and environmental governance. For historians of science, then, the Anthropocene is easy to identify. It is the preeminent "boundary object" of our time, a conceptual meeting place of distinct knowledge communities.[1]

"FROM THE PERSPECTIVE OF THE EARTH SYSTEM…"[2]

Although now an interdisciplinary concept, the Anthropocene emerged out of Earth System science (ESS). ESS dated only to the mid-1980s when the International Geosphere-Biosphere Project (IGBP) was founded to coordinate global environmental change research. For its most fervent advocates, the shift from environmental to Earth System science promised planetary salvation through revelation. At the turn-of-the millennium, John Schellnhuber, chair of the IGBP Global Analysis, Interpretation, and Modelling task force, described ESS as a "second Copernican revolution." The new perspective revealed that "our planet" was a single integrated system, which, he hoped, would inspire the "the emergence of a 'global subject'"—a unified humanity capable of democratic Earth System governance.[3]

Crutzen's and ecologist Eugene Stoermer's original short article "The 'Anthropocene'" appeared at the end of an issue of *Global Change*, the newsletter of the International Geosphere-Biosphere Project. The issue reported on a "landmark event": the February, 2000 IGBP Scientific Committee meeting in Cuernavaca, Mexico where, the story goes, Crutzen had spontaneously exclaimed that we had left the Holocene and entered the Anthropocene. Tellingly, the announcement was presented as a side note to the bigger story of the way Earth System science itself had reached a tipping point: Scientists were ready to take a "flying leap" from analyzing components of the global environment to modelling the "functioning of the Earth System as a whole."[4] This was an ambitious goal. "Integration is more than a synthetic book-keeping exercise," Schellnhuber reminded colleagues. "Remember that it took almost 4 billion years for evolution to compose the human brain from macro-molecules already available in the early days of life. The virtual scientific reconstruction of the planetary machinery ('Gaia') is not much smaller a task, although we expect it to be accomplished in less than a couple of eons."[5] In this context, Crutzen and Stoermer's desire "to emphasize the central role of mankind in geology and ecology by proposing to use the term 'anthropocene' for the current geological epoch" feels modest. If their rhetoric was

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[1] Star and Griesemer, "Institutional Ecology, 'Translations' and Boundary Objects."

[2] Steffen et al., *Global Change and the Earth System*, 117, 134, 262.

[3] Schellnhuber, "'Earth System' analysis," c20.

[4] Moore III, "Sustaining Earth's life support systems"; Fund, Rayner, and Friedlingstein, "Full-Form Earth System Models," 7-8; Uhrqvist, "One Model to Fit All? The Pursuit of Integrated Earth System Models in GAIM and AIMES."

[5] Schellnhuber, "The Waikiki Principles," 3. The taskforce subsequently substituted "Integration" for "Interpretation" in its name.

restrained, however, they still shared the Messianic mission of ESS to "guide mankind towards global, sustainable, environmental management."[6]

ESS was more than a "synthetic book-keeping exercise," but measuring global aggregate budgets of carbon, nitrogen, sediment, water and other critical planetary variables was fundamental to the whole endeavor. And big aggregate numbers generated "the shock of the Anthropocene" that attracted widespread attention from outside the global change research community: humans and their domesticates make up 97% of total terrestrial vertebrate biomass; extinction rates are 100-1,000 times preindustrial levels; anthropogenic phosphorous fluxes are 20 times greater than natural ones and Haber-Bosch reactions fix as much nitrogen as all natural processes combined; humans annually consume a third of continental biomass; 84% of non-ice land is under direct management; mineral extraction displaces three times more sediment than all rivers transport; and farming and fossil fuels have increased the concentration of greenhouse gases at rates not seen for at least 55-million years.[7] Recitations of such staggering numbers provoke an affective response similar to illustrations of deep time: if Earth's timeline were represented by the span of your arms from fingertip to fingertip, introductory geology courses inform students, then all of human history could be eliminated with the brush of a nail file.[8] Only in the new "geology of mankind" the scales of awe were reversed; humans now dominated the "great forces of nature."

Two iconic graphics became emblems of the Anthropocene. First, Will Steffen, Executive Director of the IGBP (1998-2004) and a fellow of the Stockholm Resilience Center, published two-sets of 12-graphs illustrating "increasing rates of change in human activity" and corresponding "global scale changes in the Earth system" from the Industrial Revolution to the end of second millennium [Fig. 1].[9] The 24 J-curves all become dramatically steeper around 1950, marking "the Great Acceleration" of anthropogenic change. By keeping the X-axis (time) constant and varying the units and scale of the Y-axis, the figure elided complex questions of causality and made the correlation of social and natural patterns of global change obvious in a single glance.[10]

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[6] Crutzen and Stoermer, "The 'Anthropocene,'" 18.

[7] Bonneuil and Fressoz, *Shock of the Anthropocene*, 5-14; Gaffney and Steffen, "The Anthropocene Equation," 56.

[8] McPhee, *Basin and Range*; nail file anecdote from comment by Naomi Oreskes.

[9] Steffen, Grinevald, Crutzen, and McNeill, "The Anthropocene: Conceptual and Historical Perspectives," 851-852.

[10] Smail and Shryock, "History and the 'Pre'."

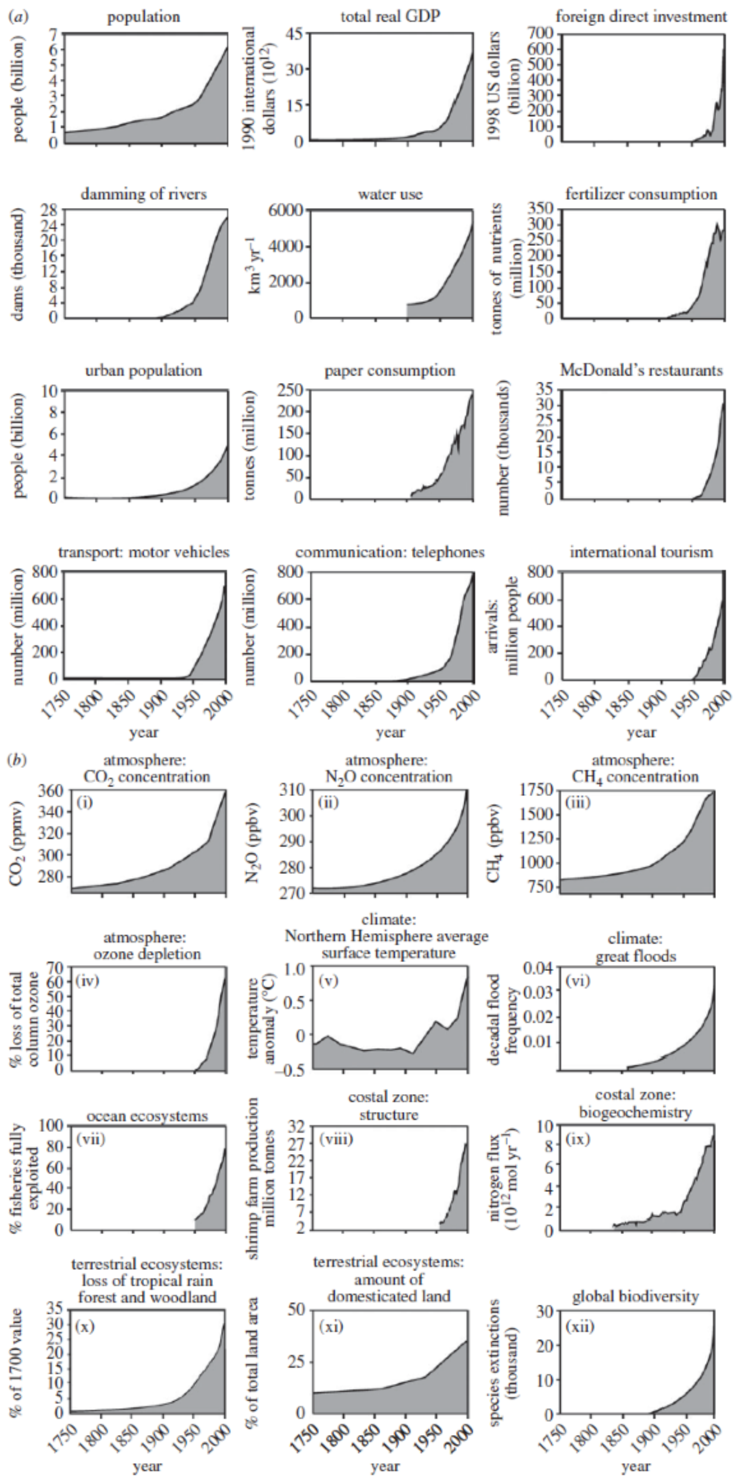

Fig. 1a and 1b. The Great Acceleration. Source: Steffen, Grinevald, Crutzen, and McNeill, "The Anthropocene: Conceptual and Historical Perspectives," 851-852.

Steffen and Johan Rockström, also affiliated with the Stockholm Resilience Center, were lead authors of the second graphic, which illustrated the concept of "planetary boundaries" [Fig. 2].[11]

Fig. 2. Planetary Boundaries. Source: J. Lokrantz/Azote based on Steffen et al. 2015.

Nine-wedges form a circle representing the vital processes necessary to sustain humanity. The center represents the state of the preindustrial Earth System and a green ring indicates

[11] Rockström, Steffen, et al. "A Safe Operating Space for Humanity."

the extent of the "safe-operating space for humanity." Moving farther out, the system crosses the boundary from safety into a yellow zone of uncertainty and then a red zone of existential peril. The state of each of the nine-processes is determined through quantitative analysis of a "control variable."[12] The ultimate effect resembled a dashboard for monitoring the Earth System. Which, of course, was precisely its ambition. Whether the analogy was to the planet as a machine or (more commonly) an organism, its creators had little doubt the Earth was breaking down and required the intervention of a competent engineer or surgeon [Fig. 3]. The "planetary boundaries" framework was an argument for expert management of the global environment.

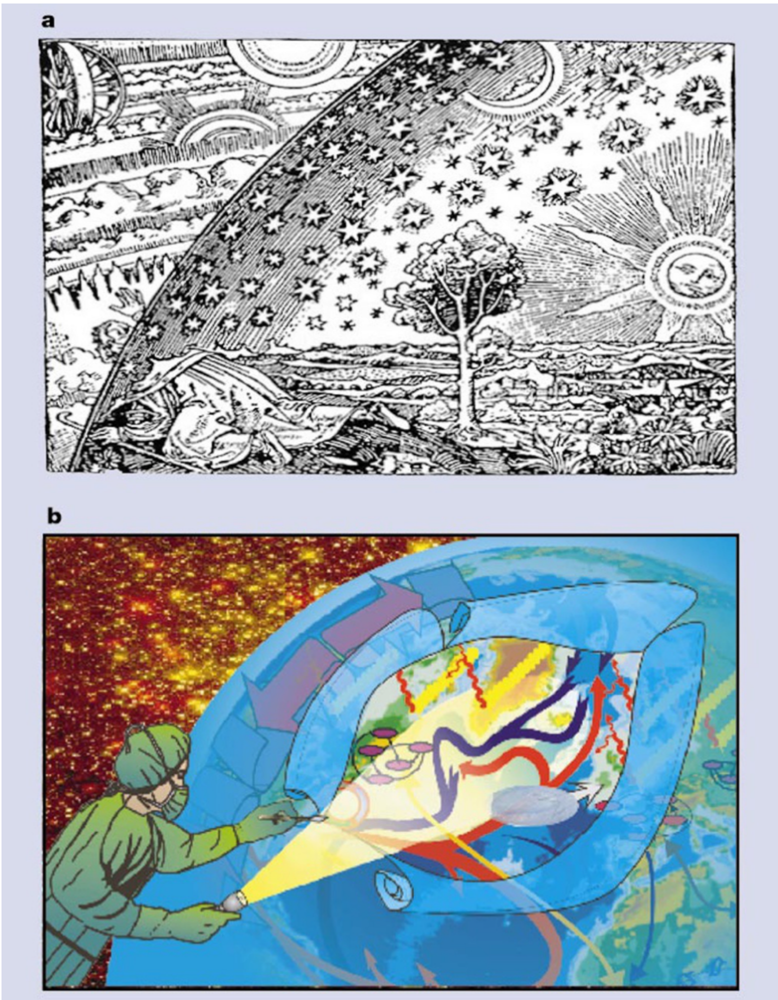

Fig. 3. Schellnhuber's 'Earth System' Analysis contrasted (b) twenty-first century 'Earth-system' diagnostics with an Enlightenment idea of interconnectivity. Source: Schellnhuber, "'Earth System' Analysis and the Second Copernican Revolution."

[12] For key publications and history of planetary boundaries research, see https://www.stockholmresilience.org/research/planetary-boundaries.html

The Anthropocene, however, was not a promotional campaign in support of large-scale geoengineering. With notable high-profile exceptions, including Crutzen himself, Earth System scientists were skeptical of risky proposals such as injecting massive quantities of aerosols into the stratosphere for "solar radiation management."[13] Most described modern civilization itself as a dangerous experiment in the functioning of the Earth System. Rather than blunt geoengineering fixes, keeping the experiment in the "safe-operating space" required reengineering society. The happy news was that survival, even a "good Anthropocene," was still possible, if society invested in and deferred to sustainability science before the window of opportunity closed.[14]

In environmentalist rhetoric, the window seemed perpetually stuck at ten-years, but ESS suggested it might unexpectedly slam closed.[15] The Earth was a complex system composed of complex subsystems; no variables were independent [Fig. 4].[16] Global change researchers measured and modelled biogeochemical cycles linking the geosphere and biosphere. Specialists further sliced the Earth into a multitude of sub-spheres (e.g., the anthrosphere, cryosphere, ecosphere, hydrosphere, lithosphere, pedosphere, stratosphere, and troposphere) and analyzed fluxes between them. Few subsystems at any scale remained in a state of equilibrium for long; stability was the anomaly, change the constant. And in complex systems, causes and effects were connected in circuitous feedback loops. Small, local changes could have dramatic global effects or, through obscure teleconnections, affect a subsystem on the other side of the planet. Buffering meant that apparently large changes sometimes barely left a mark—at least until they crossed a critical threshold that caused a "regime shift" in the whole system. In short, environmental change was nonlinear, and so "abrupt changes and surprises are a common feature of the Earth System."[17] Little wonder, then, that the ESS community was wary of heroic geoengineering schemes: by ratcheting up the pace and scale of change, technical fixes might make things worse.[18]

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[13] Anshelm and Hannson, "Has the Grand Idea of Geoengineering as Plan B Run Out of Steam?"; Crutzen, "Albedo Enhancement by Stratospheric Sulfur Injections"; Fleming, *Fixing the Sky*.

[14] Rockstrom, "Let the Environment Guide Our Development."

[15] Key synthetic documents for this history of ESS are International Geosphere-Biosphere Programme, "The Initial Core Projects"; Steffen et al. *Global Change and the Earth System*; Monks, Melamed, and Seitzinger, "The IGBP Synthesis."

[16] NASA Advisory Council, Earth System Sciences, "Earth System Science Overview."

[17] Steffen et al, *Global Change and the Earth System*, 235.

[18] Landecker, "Antibiotic Resistance and the Biology of History."

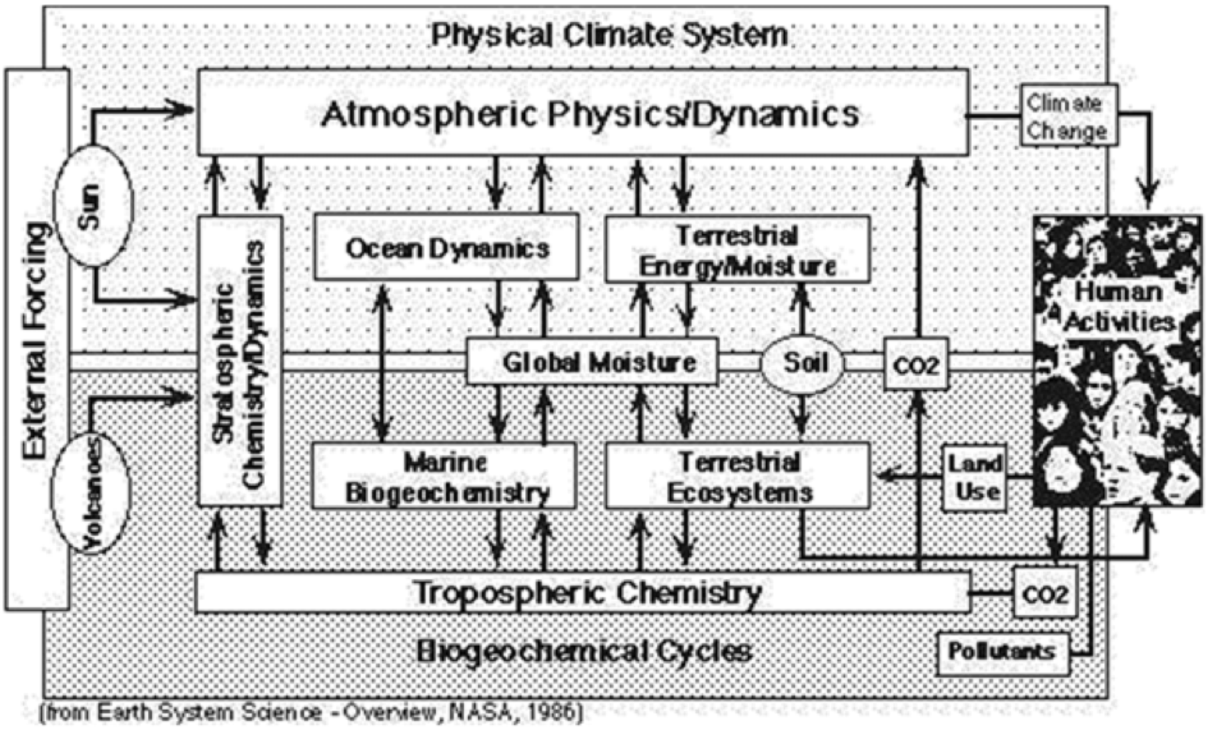

Fig. 4. The Bretherton Diagram.

Relatively recent geologic history revealed the planet's disturbing potential for rapid change. During the termination of the last glacial 12,600 years ago the slowly warming planet suddenly cooled, with temperatures in Greenland dropping at least 10^{0}C in less than a decade. The Younger Dryas, as this episode is termed, could not be accounted for by Milankovitch cycles, the subtle, smooth changes in the Earth's orbit that explained the 100,000 year periodicity of glacial-interglacial cycles. With no plausible external forcing mechanism, scientists hypothesized that massive pulses of freshwater from melting glaciers in North America diluted the salinity of the North Atlantic and disrupted the thermohaline circulation, which pumps warm surface waters from the tropics into the arctic, where they release heat, sink, and flow back South. Without this heat pump, temperatures in the North Atlantic plunged. A warming trend thus triggered a 900-year cold snap, with effects that cascaded through the biosphere and around the world.[19]

The Younger Dryas provided critical evidence—an existential moral lesson even—of the sensitivity of the Earth System. Beware poking the "angry beast," as Wally Broecker, the geochemist who helped establish the significance of the thermohaline circulation, famously

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[19] Steffen et al., Ch. 2, "Planetary Machinery: The Dynamics of the Earth System Prior to Significant Human Influence," *Global Change and the Earth System*; Marchal et al., "Modelling the concentration of Atmospheric CO_2 during the Younger Dryas Climate Event."

nicknamed the climate system.[20] From the perspective of the Earth System, then, the "safe operating space" of the Holocene—which began with the end of the Younger Dryas—was anomalous. In fact, invocations of the Holocene as an environmental baseline from which to evaluate risk in the Anthropocene exaggerate that epoch's stability.[21] It is perilous to assume, as even geographically astute twentieth-century historians such as Fernand Braudel had, that the past provided a stable environment for the gradual development of society and rapid churn of politics. Geological time was eventful.[22]

The Paleolithic past served as an experimental control; it revealed the structure and function of the Earth System without the key variable, civilization. Establishing a baseline for pre-anthropogenic global change helped determine the anthropogenic contribution to climate change. Global warming was the most important context for the emergence of the Anthropocene, but not the only one. Indeed, through the late twentieth century, the stability of the climate despite fossil fuel emissions showed the effect of systemic buffering and lags, not surprising tipping points.

The ozone hole was more emblematic of the Anthropocene's dangers. Discovered contemporaneously with the formulation of ESS in the 1980s, it demonstrated the potential for humans to trigger a "catastrophic failure" of the Earth System. Chlorofluorohydrocarbons (CFCs) used as refrigerants since the 1930s escaped into the stratosphere where trace amounts unexpectedly started a chain reaction that destroyed ozone, a vital filter shielding life from deadly UV-B radiation. CFCs proved relatively easy to limit though replacements and international agreements. But rather than a cause for celebration, Earth System scientists portrayed the episode as a warning. We had gotten lucky: industrialists had happened to develop chlorine instead of bromine refrigerants, which were 100 times more destructive of ozone; the British happened to be monitoring Antarctic ozone; and atmospheric chemists happened to have just developed the science to make sense of the phenomenon. Crutzen, who won the Nobel Prize for this work, wondered, "What other surprises may lie ahead involving instabilities in other parts of the complex Earth System?"[23]

Crutzen's question went right to a paradox at the heart of ESS: it sought to predict the future but complex systems were, by definition, unpredictable. The Anthropocene signified the intensification of this paradox. Even as experts modeled the system's past and future with unprecedented competence, the great acceleration of human impacts caused an unprecedented rate of change; in this "no analog state," the only certainty was more frequent

[20] Broecker, however, supported major geoengineering interventions, Broecker and Kunzig, "Fixing Climate."

[21] On baselines, see Ureta, Lekan, and von Hardenberg, "Baselining Nature: An Introduction"

[22] Braudel, *The Mediterranean and the Mediterranean World in the Age of Philip II*; Davies, *The Birth of the Anthropocene*; Paglia, "Not a Proper Crisis."

[23] Crutzen, "The Ozone Hole," 237.

and more extreme surprises.[24] In 2018, prophets of the Anthropocene described this terrifying future in apocalyptic terms, warning that the planet would enter an inescapable "hothouse" state unless humanity collectively assumed "stewardship of the entire Earth System" [Fig. 5a&5b].[25]

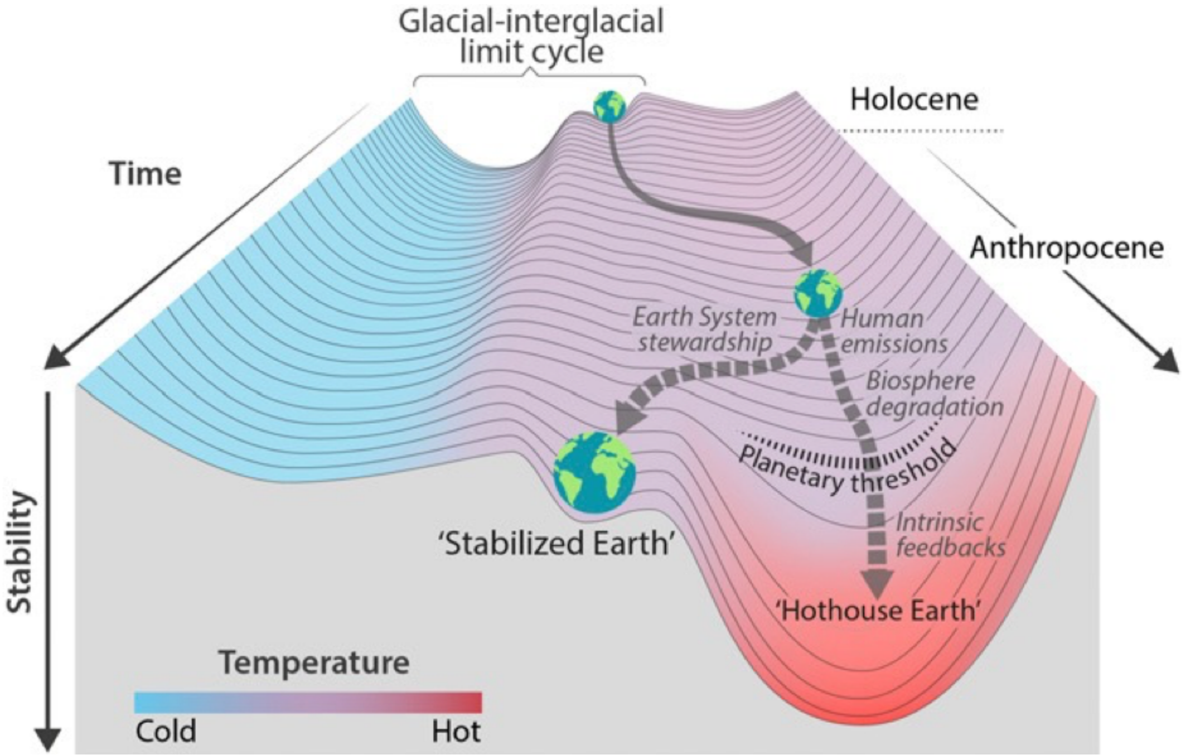

Fig. 5a: "Stability landscape showing the pathway of the Earth System out of the Holocene and thus, out of the glacial-interglacial limit cycle to its present position in the hotter Anthropocene." Source: Steffen et al., "Trajectories of the Earth System in the Anthropocene," 8254-8255.

[24] Rosol, "Hauling Data."

[25] Steffen, Rockström, Richardson, et al., "Trajectories of the Earth System in the Anthropocene," 8252.

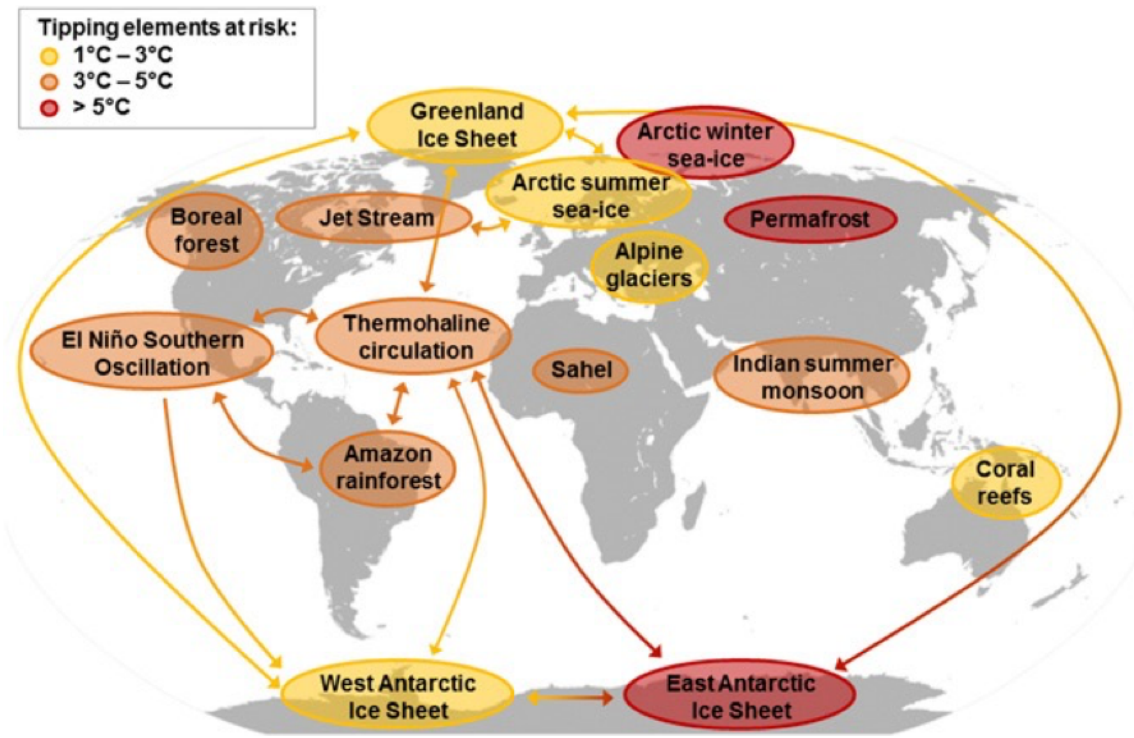

Fig. 5b: "Global map of potential tipping cascades." Source: Steffen et al., "Trajectories of the Earth System in the Anthropocene," 8254-8255.

"Trajectories of the Earth System in the Anthropocene" offered a "choice" between an uninhabitable "hothouse" and a "stabilized" Earth. Earth System scientists thus claimed the moral authority of nature to determine social behavior. The implications were troubling. In "Reducing the Future to Climate," the geographer Mike Hulme argued that the prestige of modelling empowered the "predictive natural sciences" to assert unwarranted epistemic hegemony over the future of everything from ecology and economy to social mobility and geosecurity. When "climate becomes the one 'known' variable in an otherwise unknowable future," Hulme explained, "[t]he openness, contingency, and multiple possibilities of the future are closed off."[26]

Anthropocene narratives are an example of what Donna Haraway called SF: a genre of storytelling encompassing scientific facts and fictions in which "possible worlds are constantly reinvented in the contest for very real, present worlds."[27] In classical uniformitarian geology, the causes of environmental change operating today were presumed to be the same as those operating in former worlds, and so the present was the

[26] Hulme, "Reducing the Future to Climate," 249.

[27] Haraway, Primate Visions, 5.

key to the past. In ESS' "geology of mankind," the simulated past was the key to the future. And the future was, as always, an intervention in the present.

ONTOLOGICAL RUPTURE?

The normative implications of history told from the perspective of the Earth System played out in debates over the start of the Anthropocene. Did the Anthropocene begin with the invention of the coal-powered steam engine in the late-eighteenth century, as Crutzen and Stoermer originally proposed? Or was the post-WWII Great Acceleration the moment when humans first came to dominate the great forces of nature?[28] Perhaps it originated with European conquest of the Americas, which initiated unprecedented biological exchanges, epidemics, and the birth of socio-economic world systems.[29] Climatologist William Ruddiman argued for the mid-Holocene expansion of agriculture, which increased atmospheric greenhouse gas and possibly prevented return to a Pleistocene ice age.[30] Why not the anthropogenic-driven extinction of megafauna or the domestication of plants—in other words, the entire Holocene?[31] Maybe the Anthropocene was inevitable when hominins first crafted a hand-ax or wielded fire.[32]

For stratigraphers, the geologists who maintained the official Chronostratigraphic Chart [Fig. 6], the start of the Anthropocene was not supposed to be a question of competing narratives, but an empirical matter of concern. In 2009, largely at the initiative of Jan Zalasiewicz, an expert on early-Paleozoic graptolites at the University of Leicester, the International Commission on Stratigraphy convened an Anthropocene Working Group (AWG) to determine whether Earth System scientists were right that the planet had entered a new phase and if so, when.[33] The AWG got started just as "Climategate" embroiled leading climatologists in a manufactured scandal over emails stolen by "denialist" hackers.[34] Amid the ongoing erosion of expert authority, the AWG emphasized objective criteria and the technical nature of their work. Nevertheless, the prospect of a new anthropogenic unit of deep time

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[28] Steffen, Broadgate, Deutsch et al., "Trajectory of the Anthropocene."

[29] Lewis and Maslin, "Defining the Anthropocene."

[30] Ruddiman, *Plows, Plagues and Petroleum*.

[31] Smith and Zeder, "The Onset of the Anthropocene"; Braje and Erlandson, "Human Acceleration of Animal and Plant Extinctions."

[32] Pyne, "From Pleistocene to Pyrocene."

[33] Working Group on the Anthropocene, http://quaternary.stratigraphy.org/working-groups/anthropocene/

[34] Dalby, "Framing the Anthropocene."

proved newsworthy and excited scholars and journalists who previously had no idea they'd been living in the Holocene.[35]

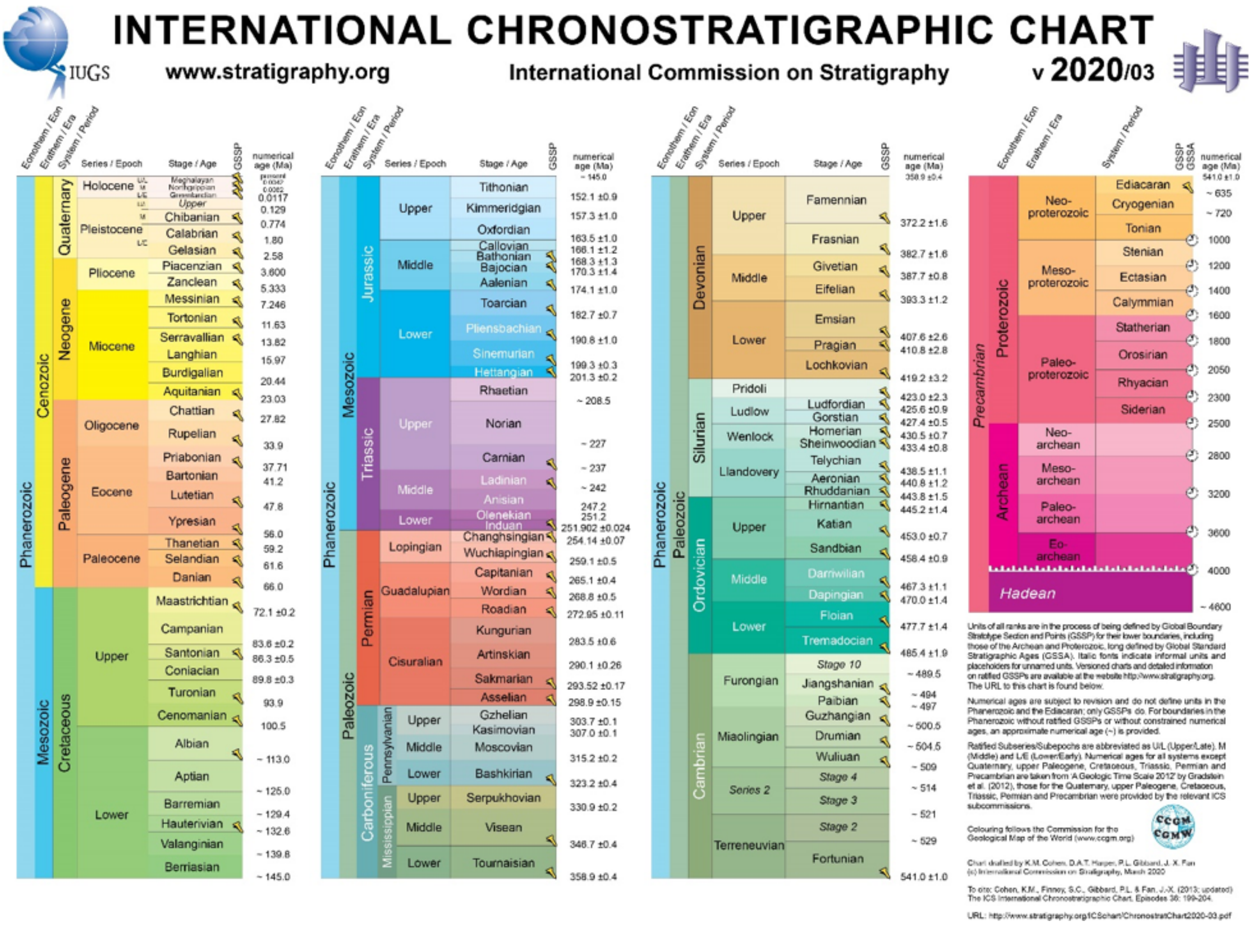

Fig. 6: Note that chart is not to scale, which accurately represents increasing resolution of geologic time perspective.

For working paleo-scientists, geologic time units facilitated global chronological correlation, a shorthand that enabled experts trained in different disciplines and exploring different places to locate their research on a common timeline. In the nineteenth century, geologists reconstructed Earth's chronology by comparing the relative position, thickness, and fossil composition of strata; biostratigraphy, the changing fossil record, indexed distinct ages. Some sense of the length of periods could be derived from such observations, but geologic time remained relative. Then in 1913, the British prodigy Arthur Holmes' *The Age of the Earth* showed how radioactive decay formed a planetary "hourglass."[36] Unstable isotopes made especially reliable chronometers because an element's half-life appeared unaffected by its

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[35] Kolbert, "The Lost World."

[36] Holmes, *The Age of the Earth*.

environment. In short, by the end of the twentieth century, the Geologic Time Scale had become a record of absolute linear time.[37] The displacement of relative time rendered the conventional units of the Geologic Time Scale explicitly conventions; they remained vital as technical shorthand, narrative devices, and boundary objects but their interpretive significance for global correlation diminished.

Since the 1970s, chronostratigraphy has sought to standardize the divisions of the Geologic Time Scale through the Global Stratotype Section and Point (GSSP). A GSSP is typically a rock outcrop with a complete stratigraphy showing the before and after of a transition (the section) and a point that marks the boundary, the so-called "golden spike." The GSSP must be credibly dated and robustly correlated with secondary stratigraphic markers in other parts of the world. Since in practice most "golden spikes" have been located in Western Europe, standardizing the GTS has meant correlating the world with European geology.[38]

Locating GSSPs for very recent geologic history posed unique challenges for two reasons. First, global-scale categorizations are more difficult with greater resolution; provincial particularism becomes more apparent as the focus sharpens. From the perspective of the Phanerozoic Eon (the 540-million year time unit in which the "modern" biosphere has operated) or the Cenozoic Era (the 66-million years since an asteroid impact ended the reign of dinosaurs) or even the Quaternary Period (the 2.6 million years of Ice Ages containing all of hominin evolution), a 10,000-year history of civilization—that is, the Holocene Epoch—is an instant. Twentieth-century innovations in analyzing pollen, plankton, and stable isotopes and in drilling cores taken from glaciers, lake bottoms, ocean floors, and loess soils produced records of environmental change at annual to century and local to global scales during the Quaternary Period. In contrast, the uncertainty in radio-isotope dating of earlier GSSPs, independent of questions of stratigraphic interpretation, typically ranged from 100,000 to more than a million years, and a typical Age (the finest-grained unit of the GTS) even in "recent" geologic history was at least twice as long as the entire Quaternary. This temporal blurring reveals global-scale patterns.

Second, locating a point in a stratigraphic section was hard to do in the absence of stratigraphy. 10,000 years is not a lot of time in the life cycle of rock, let alone the single human lifespan that has passed since the start of the Great Acceleration. Advocates of the Holocene solved this problem by locating its golden spike not in rock but in ice: a sudden decrease in excess Deuterium 1,492.45 meters down an Ice Core from Greenland signaled the end of the Younger Dryas.[39] Individual years can be distinguished in the layers of ice cores,

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[37] Gradstein, Ogg, Schmitz, and Ogg, *The Geologic Time Scale 2012*, v. 1.

[38] Gradstein and Ogg, "The Chronostratigraphic Scale," 34-37. The Earth sciences continue to struggle with diversity; for the U.S., see NSF, *Women, Minorities, and Persons with Disabilities in Science and Engineering*.

[39] Walker, Johnsen, Ramussen, et al. "Formal Definition and Dating of the GSSP (Global Stratotype Section and Point) for the Base of the Holocene Using the Greenland NGRIP Ice Core, and Selected Auxiliary Records."

providing an unparalleled high-resolution climate history. Yet the processes that transformed ice into snow and trapped air smoothed even ice's precise climate record over decades or centuries.[40] And while an ice core makes an ideal monument to the end of the Pleistocene, we live in a melting world. In short, dating the present with stratigraphy is like killing a virus with a hammer.

Necessarily, then, the Anthropocene Working Group differed from previous stratigraphic commissions. For one thing, many of its members weren't geologists or paleobiologists; for example, members included veterans of the IGBP Will Steffen and Paul Crutzen; archaeologist Matt Edgeworth and geographer Erle Ellis; even historians of science and the environment John McNeil, Naomi Oreskes, and Jacques Grinevald. Moreover, debates over the start of the Anthropocene were driven not by observations in rocks but by ESS concepts, observations, and modelling, for which stratigraphers then attempted to identify material markers.[41]

The question before the AWG was, what would a geologist in a future epoch recognize as a material signal of a global boundary? In terms of biostratigraphy, for instance, members of the AWG gang noted that "in the far future" a novel Anthropocene biota "will appear in the rock record as a geologically sharp and substantial paleaontological break between distinct pre-Anthropocene and Anthropocene strata."[42] Anthropocene rocks existed only in the process of becoming. The AWG approached this fantastic thought experiment with all the practical commonsense it could muster. Such earnest consideration of the needs of post-human planetary historians only makes the proposals for a golden spike more poignant: the replacement of diverse wild fauna with chicken fossils; subway tunnels; novel materials such as concrete and plastics; fly ash from power plants; marine dead zones; global radioactive fallout from atmospheric thermonuclear testing.[43]

Despite the initial suggestion that the Anthropocene began with the Industrial Revolution, in 2019 the AWG voted to approve the mid-twentieth-century Great Acceleration as the start of the epoch and radionuclides as the primary stratigraphic marker of its base. Votes at the higher levels of the geologic bureaucracy will probably be more contentious. Leading stratigraphic experts complained that establishing an official unit would be a political stunt. The Chair of the International Commission on Stratigraphy warned that any formal proposal "should recognize that events of a proposed Anthropocene are those directly observed and

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[40] Raynaud and Blunier, "The Ice Record of the Atmospheric Greenhouse Trace Gases," 14; Antonello and Carey, "Ice Cores and the Temporalities of the Global Environment."

[41] Zalasiewicz, Stefen, Leinfelder, et al, "Petrifying Earth Process."

[42] Zalasiewicz, *The Anthropocene as a Stratigraphic Unit*, 33.

[43] Zalasiewicz, *The Anthropocene as a Stratigraphic Unit*; Waters, Zalsiewicz, Sumerhayes, et al., "Global Boundary Stratotype Section and Point (GSSP) for the Anthropocene Series."

precisely dated with human chronometers and calendars, and would not be interpreted from its marginal and impoverished stratigraphic record."[44] However the new epoch is eventually represented on the International Chronostratigraphic Chart, the debate made it clear that the Anthropocene is here to stay.

MULTIPLYING 'CENES

Each proposed origin story shifted the meaning of the Anthropocene as a metaphor for the present, but they all had something in common: they were already starting or turning points of world history textbooks. The earliest potential beginnings, fire and megafauna extinction, implied that the instinct to eat the future was coded deep in *Homo sapiens'* DNA; the Anthropocene was simply the inevitable product of human nature.[45] A direct line from the agricultural revolution to the contemporary global environmental crisis risked recapitulating a Eurocentric stadial history of civilization from the Neolithic revolution through the urban revolution to the industrial revolution—and with it the racialized ranking of cultures from noble savages who lived in harmony with nature to industrious Europeans possessing world making and destroying agency.[46] Colonialism, capitalism, plantations, fossil fuel economies: all were reduced to mere epiphenomena. This is, as historian Kenneth Pomeranz puts it, the "trick of perspective" that allows "revolutions" to substitute for explanations.[47] Zooming out to a longer temporal scale turns a complex process into an event that fits a pattern; zooming in turns a revolution into a complex, contingent process. Such moves can do important analytic work—or they can create a satisfying illusion of intellectual illumination.

Teleology is inherent in the project of crafting coherent and meaningful large-scale historical narratives; the seeds of the present must be planted in the soil of the past. But when the origin is reduced to a single seed, "the openness, contingency, and multiple possibilities of the [past] are closed off," as Hulme complained about climate modelling's effect on the future. Telling history from the perspective of the Earth System can exacerbate this deterministic tendency of grand narratives. ESS analyzes biogeochemical cycles; that is, fluxes of atoms between planetary spheres. The middle range, the scale at which we experience life, is mostly missing. Plants and animals become fleeting pools of carbon, hydrogen, oxygen, and nitrogen. It is a powerful perspective that comes at a cost: at times it

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[44] Finney and Edwards, "The 'Anthropocene' Epoch: Scientific Decision or Political Statement," 9; for Anthropocene enthusiasts' response, Vidas, Zalasiewicz, Steffen, et al., "The Utility of Formalisation of the Anthropocene for Science."

[45] Malm and Hornborg, "The Geology of Mankind."

[46] Morrison, "Provincializing the Anthropocene"; Head, "Contingencies of the Anthropocene."

[47] Pomeranz, "Teleology, Discontinuity and World History," 218; Bailey, "Time Perspectives, Palimpsests and the Archaeology of Time."

feels like organisms exist in ESS only as metaphor—not as fleshy, hungry, fascinating beings with their own purposes.[48]

Tellingly, perhaps the most successful attempt to integrate society into ESS' conceptual framework superseded humans altogether. Peter Haff, a geoscientist, proposed the technosphere, an emergent system that "includes the world's large-scale energy and resource extraction systems, power generation and transmission systems, communication, transportation, financial and other networks, governments and bureaucracies, cities, factories and myriad other 'built' systems, as well as all the parts of these systems, including computers, windows, tractors, office memos and humans."[49] The technosphere coevolved with civilization, but became "autonomous"; humans may influence some components, but as an independent system, the techonsphere has its own rules and trajectory. Indeed, while humans benefit from its services, their behavior is highly constrained by the existential imperative to maintain the system.

Humanists, however, recognized that the Anthropocene narrative raised fundamental questions about what it meant to be human and had no intention of losing their subject in the system. In an influential 2009 article, Dipesh Chakrabarty proposed that the Anthropocene marked "the collapse of the age-old humanist distinction between natural and human history" and demanded renewed appreciation of the need for universal history.[50] In fact, pockets of scholars across the humanities had been exploring this hybrid world of nature-culture for decades, but arguments for a species-level history from the author of *Provincializing Europe* (2000), the seminal postcolonial critique of social theory's Eurocentric universalism, became a touchstone for scholars in the human sciences.

Critiques from the social sciences and humanities targeted the homogenizing universalism of the Anthropocene narrative.[51] ESS actually described a planet whose history always had been contingent and multiple, characterized by time-transgressive, geographically variable phenomena at timescales relevant to human history. The iconic graphics of the Anthropocene, however, aggregated all this diversity into a single figure. Instead of contributing to this final synthesis, many humanists understood their task to be disaggregating the narrative.[52] Thus, Christophe Bonneuil and Jean-Baptiste Fressoz playfully organized their multilayered history of the Anthropocene into chapters on the Thermocene

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[48] Mitman, "Hubris or Humility? Genealogies of the Anthropocene"; for the place of organisms in the Anthropocene, see Thomas, "History and Biology in the Anthropocene."

[49] Haff, "Humans and Technology in the Anthropocene: Six Rules," 127; Rosol, Nelson, and Renn, "Perspectives on the Anthropocene."

[50] Chakrabarty, "The Climate of History: Four Theses."

[51] Palsson, "Reconcetualizing the 'Anthropos' in the Anthropocene"; Castree, "Speaking for the 'People Disciplines."

[52] Toivanen, Lummaa, Majava, et al. "The Many Anthropocenes."

(CO_2), Thanatocene (war), Phagocene (consumption), Phronocene (environmental reflexivity), Agnotocene (growth economics), Capitalocene (capitalist world systems), and Polemocene (environmental resistance).[53] Others added still more ‘cenes: Aerocene, Necrocene, Pyrocene, Chthulucene, Plasticene, Plantationocene.[54] In different ways, each of these ‘cenes pushed back against the Anthropocene’s species-level history, displacing the unmarked Anthropos in order to identify specific socio-ecological systems (capitalism, colonialism, plantation slavery) responsible for ruining the world. These alternative ‘cenes placed global environmental history within racial, class, and even multispecies justice frameworks. Rather than a technocratically engineered “good Anthropocene,” they envisioned desirable futures made possible by radically new political alliances.[55]

For many scholars in the human sciences, however, the problem was not just the Anthropocene’s universalism, but its implicit Eurocentrism. The proliferation of alternative ‘cenes hardly solved this problem since their insistence on assigning proper accountability only intensified the focus on European ways of life. People had been domesticating landscapes on a large scale but according to quite different patterns in other parts of the world for millennia. How, for example, did the Capitalocene or Plantionocene illuminate any better than the Anthropocene China’s “3,000 years of unsustainable growth” or the 13,000-year history of indigenous people manipulating the structure and function of the Amazon forest?[56] Archaeologist Kathleen Morrison captured the sentiments of many scholars of the global South and of deep history in her pointed call for “provincializing the Anthropocene.”[57]

Provincializing these ‘cenes is necessary to realizing their potential to forge new alliances for environmental justice. Anthropocene narratives wield terrifying scenarios as spurs to action in the present, but, as Potawatomi environmental philosopher Kyle Whyte argues, such warnings of impending global catastrophe “erase” the experiences of indigenous peoples around the world who have inhabited post-apocalyptic worlds for centuries. They have already suffered the violent dispossession of colonialism: forced migrations into harsh, unfamiliar environments; extinction of species inextricably enmeshed in traditional ways of life; decimating epidemics; economic collapse. From this perspective, warnings of coming catastrophes “unless ‘we’ act now” ring hollow. In fact, the post-apocalyptic worlds indigenous people inhabit today are the realization of the prophets of the Anthropocene’s own ancestors’ fantasies of domination. Honoring indigenous experiences could open

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[53] Bonneuil and Fressoz, *The Shock of the Anthropocene*.

[54] areocene.org; Haraway, *Staying with Trouble*; Moore, *Anthropocene or Capitalocene?*; “The Plantationocene Series,” https://edgeeffects.net/plantationocene-series-plantation-worlds/ .

[55] Latour, “Telling Friends from Foes in the Time of the Anthropocene”; Tsing, *The Mushroom at the End of the World*.

[56] Elvin, “3,000 years of unsustainable growth”; Roosevelt, “The Amazon and the Anthropocene.”

[57] Morrison, “Provincializing the Anthropocene.”

possibilities for stronger alliances between environmental and indigenous communities, but, Whyte explains, it requires accepting nonlinear, spiraling temporal sensibilities at odds with the totalizing epochs of geology. Indigenous people, one might say, were living the Anthropocene's dystopian future while Europeans were still plotting their path out of the Holocene.[58]

Anthropocene discourse was not central to the climate and environmental movements' shift from a sustainability to justice framing in the twenty-first century. And yet despite—or, rather, because of—a multitude of incisive critiques, the Great Acceleration of Anthropocene publication keeps pace with carbon emissions. "The political leverage of the Anthropocene concept," in contrast to alternatives like the Capitalocene, writes Gabrielle Hecht, "lies precisely in its analytic potential to bring together researchers across the natural, social and human sciences—as well as the arts—in order to better understand the complex dynamics that put our species at risk." For participants in Anthropocene discourse focused on discovering sustainable solutions, the promise lies in integrating expertise in a transdisciplinary synthesis. But as a boundary object, the Anthropocene works not by seamlessly integrating diverse perspectives, but rather by providing a forum in which scholars can preach to other communities' choirs. The faith that these communities have something to say to each other, however, implies that there is value to a universal story. Hecht's comment came in the context of describing a particular "African Anthropocene" in which colonial legacies and the logics of global capitalism led to disproportionate accumulations of poisons in African airs, waters, and bodies. Yet a species history remained important—not because it helped explain the international drivers of toxic exposures, but because it demanded that you care: "there is no planetary 'we' without them."[59] In the Anthropocene, universalism is analytically vapid but a moral bottom line.

EPISTEMIC RUPTURE?

The multiplication of 'cenes suggested the value of a nested periodization with multiple beginnings that was attentive to continuities as well as ruptures, but zealous proponents of the Anthropocene within the human sciences rejected this approach. Environmental philosopher Clive Hamilton and historian Jacques Grinevald insisted that celebrating precursors or early origins of the Anthropocene was a dangerous "deflationary move"; doing so "gradualizes" the new epoch, obscuring the paradigm shift and its "suddenness, severity, duration and irreversibility."[60] Emphasizing continuity was a mistake for planetary history and even more for the history of science. In the new geology of mankind, there was no time for

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[58] Whyte, "Indigenous science (fiction) for the Anthropocene"; Turnbull, "Territorializing/decolonizing South American Prehistory."

[59] Hecht, "The African Anthropocene."

[60] Hamilton and Grinevald, "Was the Anthropocene Anticipated," 8-9; Hamilton, "The Anthropocene as Rupture."

the old incremental, linear progress of science. An epistemic gestalt shift—a rabbit one moment, a duck the next—was essential to the meaning of the Anthropocene.

Hamilton and Grinevald's insistence that ESS represented a Kuhnian scientific revolution was a reaction to the fact that introductions to the Anthropocene often begin with a list of precursors: Comte du Buffon, whose monumental *Les Epoques de la Nature* (1788) included a final epoch of man; George Perkins Marsh, the American savant recognized as an ancestral founder of environmental history for his tome *Man and Nature* (1864), which argued human exploitation had disastrously modified the Earth and became the patron saint of the influential 1955 conference "Man's Role in Changing the Face of the Earth"; the Italian geologist Antonio Stoppani, who named an "anthropozoic era" (1873); the geologist Joseph LeConte's proposal for a "psychozoic era" (1877); and so on through the twentieth century.[61] The problem with such gestures is the lack of historical context; like proxy data recorded in different functional states of the Earth System, similar language has very different meanings in different historical contexts (or, if ignored, little meaning at all).

Nevertheless, the emergence of the "perspective of the Earth System" is better understood through metaphors of development than of rupture.[62] In the social sciences, Durkheimian social theory analyzed society's physiology and various schools of functionalism dominated social thought. More importantly, with the rise of Earth System thinking, scientists and historians have renewed appreciation for the legacy of Vladimir Vernadsky (1863-1945), a Russian soil scientist who founded the field of biogeochemistry.[63] In the 1920s, Vernadsky, depicted "the biosphere" as a coherent, self-generating zone extending from the bedrock to the top of the atmosphere—a perspective that directly influenced the post-WWII establishment of modern ecosystem science.[64] The Anthropocene's cultural roots go much deeper than the twentieth century "age of system," of course.[65] ESS' obsession with fluxes between land, water, air, and life; its anxiety over the disturbance of fragile equilibria; its attention to the particular distribution of influences, from distant stars to invisible particles, at specific moments in specific places; and its fundamental guiding metaphor of the world

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[61] Lowenthal, "Origins of Anthropocene Awareness."

[62] Oldfield, "Paradigms, Projections and People."

[63] Ackert, *Sergi Vinogradskii and the Cycle of Life*; Rispoli and Grinevald, "Vladimir Vernadsky and the Co-evolution of the Biosphere, the Noosphere, and the Technosphere."

[64] Benson, *Surroundings*, 122-127; Hagen, *An Entangled Bank*.

[65] Heyck, *Age of System*

as a body: this is the Hippocratic tradition that dominated Western natural philosophy for more than two millennia.[66]

The Anthropocene is not merely a modern manifestation of age-old metaphors, however. To give empirical substance to bold assertions about the structure and function of the Earth, scientists needed global-scale environmental data. The long struggle of imperial elites in metropolitan "centers of calculation" to train far-flung observers to divide the world into standardized categories—to achieve objectivity—has been a central theme of history of science.[67] Because of meteorology's practical importance and need to decipher large-scale moving patterns, it often led these data collection efforts, and the establishment of the International Meteorological Organization in the 1870s is a plausible start for designs of a "vast machine" to monitor the planet.[68] For a history of the Earth System, however, the Second World War marks a threshold moment. Leading environmental historians are more precise: 1948 marks the birth of "the environment," with popular books warning that population growth and soil degradation left "our plundered planet" with only a narrow "road to survival."[69] Beneath the polemics, scientists and civil servants in the postwar period assembled the modern international knowledge infrastructure: the hardware (instruments, cables, computers, satellites) and software (taxonomies, standard operating procedures, advisory committees, disciplinary norms) that make credible global-scale environmental data.[70]

Postwar fears of nuclear apocalypse made life on Earth appear vulnerable. Atmospheric atomic bomb tests illuminated global teleconnections and biogeochemical fluxes; fallout from explosions in the South Pacific showed up in baby teeth in Missouri and a new generation of ecosystem scientists traced radioactive isotopes through air and water into plankton and up the food chain into thyroids.[71] With the Cold War framing the entire planet as a battlefield, the superpowers, particularly the United States, poured unlimited resources into knowing the global terrain, from the deep ocean trenches where submarines lurked to the Arctic ice fields that separated the superpowers to currents in the atmosphere where bombers ceaselessly patrolled.[72] The space race even rocketed mankind into the final

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[66] Glacken, *Traces on the Rhodian Shore: Nature and Culture in Western Thought from Ancient Times to the End of the Eighteenth Century*. Berkeley: University of California Press, 1967; Rosenberg, "The Therapeutic Revolution."

[67] Latour, *Science in Action*.

[68] Edwards, *A Vast Machine*.

[69] Warde, Robin, and Sörlin, *The Environment*. 8-11; Osborn, *Our Plundered Planet*; Vogt, *Road to Survival*.

[70] Edwards, *A Vast Machine.*

[71] Egan, *Barry Commoner and the Science of Survival*; Martin, "Proving Grounds."

[72] Cloud and Reppy, "Earth Sciences in the Cold War."

frontier. Instead of granting freedom from Earthly constraints, however, it planted a constellation of satellites with lenses turned back on our ever-shrinking planet. Equally important for a history of ESS, military investments nurtured cybernetic theories of systems governed by feedback loops and developed computers powerful enough to model weather.[73] In sum, superpower fear-mongering inspired a new genre of catastrophic environmentalism and Cold War investments built the high-tech observational infrastructure that provides a synoptic view of the Earth System.[74]

It is hard to overestimate the importance of the Cold War in developing the hardware of the global knowledge infrastructure, but it has proven easy to underestimate the contribution of the pursuit of peace to the software. In the 1940s, internationalist intellectuals blamed the political catastrophes of two world wars on the failure of individuals and nations to recognize their membership in the "world community." Parochial political institutions and cultural patterns lagged behind the reality of economic and social interdependence. The United Nations, they hoped, represented the embryo of democratic world government, which would gain legitimacy by demonstrating its capacity to solve mundane problems that crossed political borders such as hunger and infectious disease. The global-scale environment as a social and political reality emerged out of this internationalist imperative to create world citizens—or, in Schellnhuber's language from the end of the century, to catalyze the emergence of a "global subject."[75]

International scientific programs were central to this "functionalist" strategy for manifesting the "unity in diversity" of the world community. The most successful programs balanced national interests with internationalist ideology and basic science with practical applications. The International Geophysical Year of 1957-58 established the model for large-scale, multinational scientific programs.[76] IGY coordinated national scientific programs to conduct synoptic measurements of planetary physics. Its highlights included the Soviet launch of Sputnik, the first satellite, and the start of Charles Keeling's measurements of atmospheric carbon dioxide on Mauna Loa. It also inspired biologists to launch their own International Biological Program, which after a successful decade transitioned into UNESCO's Man and the Biosphere Program in the early 1970s.[77] Unfortunately, although the internationalist ideal of unity in diversity animated these projects and both sides of the Cold War participated, in

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[73] Mackenzie, "The Influence of the Los Alamos and Livermore National Laboratories on the Development of Supercomputing."

[74] Hamblin, *Arming Mother Nature*; Masco, *Arming Mother Nature*; Higuchi, *Political Fallout*. For a longer history of catastrophic environmental thinking, Sepkoski, *Catastrophic Thinking*.

[75] Selcer, *The Postwar Origins of the Global Environment*.

[76] Needell, *Science, Cold War, and the American State*; Edwards, 202-207.

[77] Aronova, Baker, Oreskes, "Big Science and Big Data in Biology."

practice the perspectives of the scientific great powers—Europe, North America, Australia, and Japan—dominated.[78] Still, the explosion of postwar international organizing succeeded in building an international knowledge infrastructure so that when environmental issues suddenly appeared on the international agenda in the late-1960s, it was possible to identify the global environment as a coherent, endangered thing.

1972 marks a clear post-war moment of transition that presaged the Anthropocene. Following the surprising mass appeal of Earth Day two years prior and amid a wave of new environmental legislation in the United States, Japan, and Europe, intellectuals heralded the *Blue Marble*, NASA's first photograph of the whole Earth from space, as sparking a second Copernican Revolution that would usher in a new era of planetary stewardship.[79] Key events that year lent credence to the promise. First, the UN Conference on the Human Environment (the Stockholm Conference) made global environmental governance a core function of the international bureaucracy.[80] Second, the Club of Rome's controversial publication *The Limits of Growth* presented the dismal findings of an MIT team's World3 computer model, which Earth Systems scientists still celebrate as the first model of a coupled socio-ecological global system [Fig. 7].[81] Third, James Lovelock introduced the Gaia hypothesis in 1972, his and Lynn Margulis' argument that the planet was a living self-regulating system kept in a state of homeostasis (i.e. organic equilibrium) "by and for the biosphere."[82] Gaia's teleological attribution of purpose to the planet was controversial from the start and its emphasis on a continuous steady state has not fared well, but the audacious move to conceive of Earth as a single system of interlinked feedback loops is a direct ancestor of ESS.

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[78] Selcer, *The Postwar Origins of the Global Environment*, 173-205.

[79] Rome, *The Genius of Earth Day*; Cosgrove, "Contested Global Visions."

[80] Selcer, *The Postwar Origins of the Global Environment*, 206-243.

[81] Meadows, Meadows, Randers, and Behrens III, *The Limits to Growth*.

[82] Lovelock, "Gaia as Seen through the Atmosphere"; Lovelock and Margulis, "Atmospheric Homeostasis by and for the Biosphere: The Gaia Hypothesis"; Latour, "Why Gaia Is Not a God of Totality."

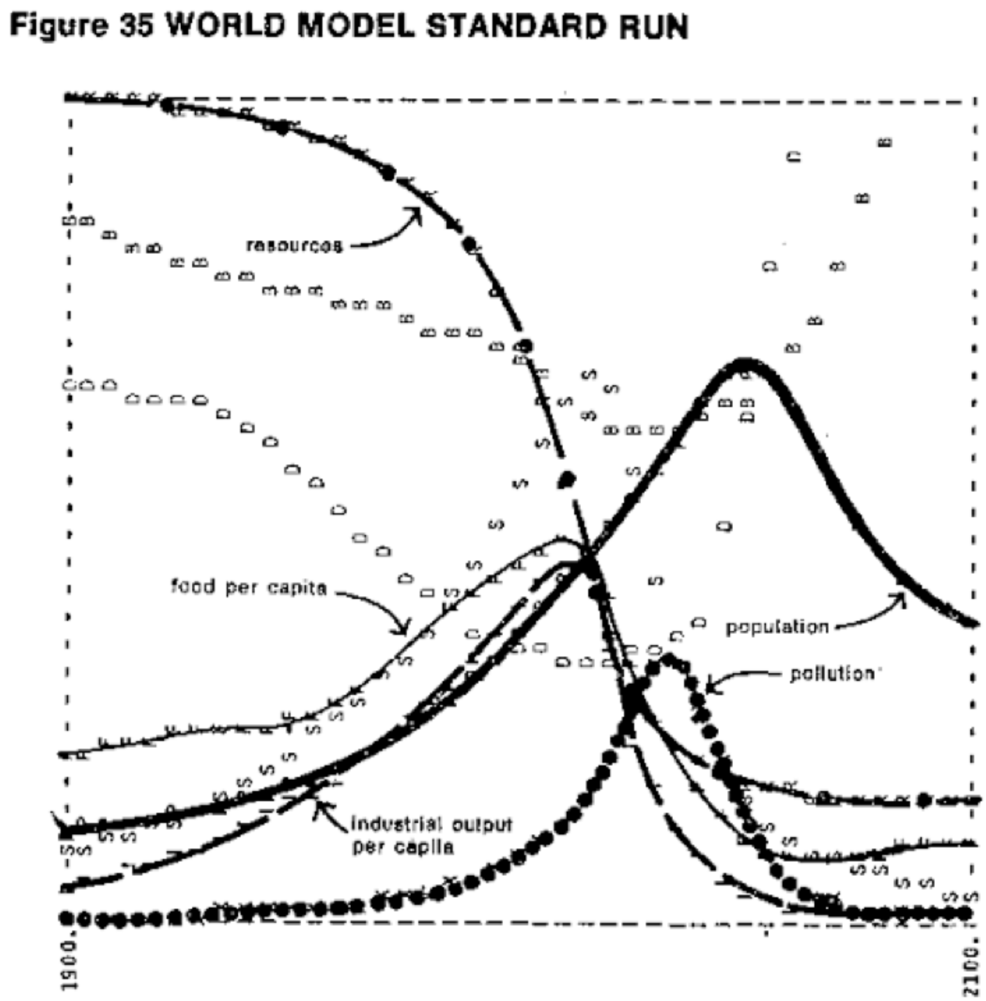

Fig. 7: From *Limits to Growth*.

The events of 1972 had their own slogan, too: "Spaceship Earth." More clearly metaphorical and explicitly normative than the Anthropocene, Spaceship Earth shared the implicit imperative that humanity recognize its responsibility to maintain its own life-support system.[83] "Spaceship Earth" had a more fleeting popularity than the Anthropocene, but it signified the origin of the global environmental governance project.

The development of the International Geosphere-Biosphere Project in the mid-1980s explicitly represented a synthesis of the earlier international geophysical and biological programs and followed their organizational blueprints, but internationalist ideals were muted. Instead of realizing the dream of unity in diversity, the 1970s had proved to be "the age of fracture": the postwar Keynesian consensus on the value of expert-guided, state-led

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[83] Monks, Melamed, and Seitzinger, "The IGBP Synthesis," 1.

development planning dissolved in the rising tide of neoliberalism; environmental regulation became a polarized, partisan flashpoint; and as former colonies gained a majority in the UN General Assembly, the United States pulled back from the vision of a liberal democratic international community.[84] When planning commenced for the IGBP, the United States and Britain had withdrawn from UNESCO and East Bloc scientists were marginalized in a program closely associated with NASA.[85] "Sustainable development" provided a new policy framing and increasing anxieties about global warming added a sense of urgency. Working with partner programs like the World Climate Research Program (1980) and the International Panel on Climate Change (1988), the IGBP expertly balanced fundamental science and practical application.

IGBP participants situated the history of ESS in the drama of natural history instead of institutions or postwar politics, but the suppressed internationalist ideals quietly endured.[86] By the time the program teamed up with other global change projects to form "Future Earth" in 2015, participants were focused on building international "knowledge-action networks" and calling for "a loyalty not to country but to Earth" in ways that recalled the world community of 1948.[87] Rather than reducing the future to climate and demanding technocratic control, leading Earth System scientists were calling for a "diversification of models" at multiple scales and experimenting with ways of engaging "stakeholders" in model development, interpretation, and scenario-building.[88] Such participatory approaches hope to intervene in the politics of the present by expanding the range of imagined plausible and desirable futures.[89]

CONCLUSION

From the perspective of geologic time, the Anthropocene is not an Epoch but a moment, not solid rock but the mud between our toes. It is the threshold on which humanity is poised.[90] Recognizing that the present represents a rupture in the unfathomable depths of Earth history generates the shock of the Anthropocene. Ironically, the effort to officially establish the Anthropocene as a geologic time unit depended on the ultimate deflationary move: the pose that the particular moment and marker were merely pragmatic conventions facilitating

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[84] Rodgers, *Age of Fracture*; Selcer, *The Postwar Origins of the Global Environment*, 237-244.

[85] Rispoli and Olsakova, "Science and Diplomacy around the Earth."

[86] Uhrqvist and Linnér, "Narratives of the Past for Future Earth."

[87] Robin and Steffen, "History for the Anthropocene," 1712; Future Earth, "Knowledge-Action Networks."

[88] Verburg, Dearing, Dyke, et al., "Methods and approaches to modelling the Anthropocene."

[89] Bai, Leeuw, O'Brien, et al. "Plausible and Desirable Futures in the Anthropocene."

[90] Siri, Veland and Amanda H. Lynch, "Scaling the Anthropocene"; Paglia, "Not a Proper Crisis."

standardization.[91] Any symbolic resonance of proposed golden spikes was purely coincidental; causal explanation, moral judgement, and political relevance were irrelevant. Yet reducing the golden spike to a convention cuts against the qualities that have made the Anthropocene such an effective boundary object: productive misunderstandings, metaphorical borrowings, alternative framings, data-set juxtapositions, and competing narratives.

Rather than nailing down a final transdisciplinary synthesis, this undisciplined Anthropocene generates troubling conceptual frictions. It is manifested in the playful practices of the "Anthropocene Curriculum," a long-running, Berlin-based, international collaborative network that organizes workshops, exhibitions, field trips, and other happenings that bring together scientists, humanists, artists, and activists to "co-develop curricular experiments that collectively respond to the crisis of the customary."[92] Or in *Future Remains*, a multistage project including an "Anthropocene slam," writing workshop, and museum exhibition, all culminating in an essay collection. Instead of a single golden spike, these scholars created an iconoclastic "cabinet of curiosities for the Anthropocene." All the symbolism, moral conviction, causal finger-pointing, and emotion that are normally drained from a standardized stratigraphic boundary marker imbued the objects in the cabinet: a jar of sand collected on an artificially "nourished" North Carolina beach; a cryogenic freezer box for preserving endangered DNA; an artificial coral reef; a cheery DDT pesticide pump for the 1950s homemaker; a recording of a Maori man singing an extinct bird's song, and many more. The cabinet of curiosities explicitly rejected the standardizing classification impulse of modern science and instead embraced an earlier era's fascination with the unexpected wonders of natural history.[93] The promise of this seriously playful, boundary-breaking mode of multidisciplinary exploration explodes from the screen in *Feral Atlas: The More-Than-Human Anthropocene*, a wildly creative digital maze of unexpected relations.[94] The capacity to put apparently opposed approaches into conversation has made the Anthropocene the conceptual frame of choice for "planetary social thought" today.[95]

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[91] For a crystallization of this dilemma, see the debate over Lewis and Maslin's proposal for the "orbis spike" of 1610 as a golden spike coinciding with the colonization of the Americas, in *The Anthropocene Review* 2, no. 2 (2015).

[92] HKW, https://www.hkw.de/en/programm/projekte/2014/anthropozaen_curriculum/anthropozaen_curriculum_1.php; for an introduction to artists contributions, see Davis and Turpin, *Art in the Anthropocene*.

[93] Miman, Armiero, Emmett, *Future Remains*.

[94] Tsing, et al., *Feral Atlas*.

[95] Clark and Szerzynski. *Planetary Social Thought*.

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