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Geographies of science and technology II: In the critical zone

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Abstract

Amidst an unfolding environmental crisis, suspicion about the totalising and homogenising spatial grammars of the 'Anthropocene' has spurred the development of a new spatial concept which, its proponents hope, can better ground the science and politics of environmental change in local geographies. In this second report on science and technology, I use this concept as a lens onto recent work in geography concerned with the space-times of 'environmental' sciences and technologies, broadly construed. The notion of the 'critical zone', and the practice of 'critical zone science', directs our attention to geographical work on situated practices of interdisciplinarity, on new modes of producing and working with 'big data', and on the volumetric, vertical and subterranean spaces of technoscientific practice. Emerging research has also engaged with the technologisation of critical zone management, while new insights into 'lively capital' and nonhuman labour push us to see the critical zone not just as an increasingly technologised space, but as itself a technology of human autopoiesis. Amidst the febrile politics of sustaining this planetary living-system, new questions are being asked about what it means to be critical in the critical zone.

Keywords

Science, technology, anthropocene, critical zone, verticality, data, geoengineering

I In the zone

The notion of 'the critical zone' first emerged in US environmental science communities around the turn of the millennium, to describe the 'heterogeneous, near surface environment in which complex interactions involving rock, soil, water, air, and living organisms regulate the natural habitat and determine the availability of life-sustaining resources' (National Research Council, 2001). The criticality of this zone was posed in terms of its support for human (and indeed, most other forms of) life, and William L. Graf was quick to point out that this was, traditionally, very much the terrain of geography (Graf, 2004). Critical zone science called for more interdisciplinary cooperation and more support for close empirical observation. In institutions like the US Geological Survey, Graf contended, this arguably strengthened the position of geographers, including human geographers, who could contribute to the work of both better describing and better managing the life-giving interacting systems (including social and political systems) of the 'near surface environment'. A network of 'critical zone observatories' was established by the National Science Foundation to closely study the biogeochemical entanglements between the base of active groundwater and the top of the vegetative

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canopy, with the intention of combining local insights to develop new understandings of environmental processes across scales (Brantley, 2020; Giardino and Houser, 2015). Although funding has been unstable, the Critical Zone Observatory network has recently become the Critical Zone Collaborative Network (see www.criticalzone.org), and 'critical zonologists' are multiplying (Brantley, 2020).

In a short 2014 paper, Bruno Latour outlined his thinking on why 'the critical zone' offered an important new way of approaching ecological politics. He took the 'critical zone' to denote 'a spot on the envelope of the biosphere', or even on 'Gaia's skin', shifting the universal gaze upon a singular, planetary critical zone towards a 'leopard's skin' pattern of multiple, heterogeneous critical *zones*, existing at scales from a garden to the Amazon basin (Latour, 2014: 4).[1] Within these zones could be readily observed the entanglement of heterogeneous agencies: instead of 'The Human' acting on 'Nature', or even human geographies layered on top of physical geographies, 'critical zonists', as he calls them, might identify and follow the kinds of chain of connection familiar to readers of actor-network theory: 'To trace the nitrogen cycle might bring you just as quickly to enter a (human made) factory as following (nature made) calcium release from rock would lead you to study some regulations imposed by forest engineers who had read new textbooks on soil management' (ibid: 5).

A critical zone orientation could foster new kinds of cross-disciplinary working, offer a new way of recognising critical zonists as active participants in (rather than detached observers of) the political process of composing a common world, and help skirt the paralysing abstractions of planetary politics in favour of trans-disciplinary forms of local stewardship and care. The critical zone is critical in relation to life – it is the 'living-system' (McKittrick, 2021: 2) – and for Latour suggests a set of interwoven systems and relations that are not given but always in a state of potential collapse, and thus requiring constant attention and care: 'the notion entails an attention, a capacity to feel what happens and the necessity to be cautious, careful, clever and informed in a way that would be different if the zone was just a chunk of 'space' (Latour, 2014: 4).

Latour's critical zone work to date culminated in a multidisciplinary 'thought-exhibition' co-curated with long-time collaborator Peter Weibel, with a book entitled *Critical Zones: The Science and Politics of Landing on Earth* (Latour and Weibel, 2020), which mirrors their earlier, influential coffee-table-philosophy offerings *Iconoclash* (Latour and Weibel, 2002) and *Making Things Public* (Latour and Weibel, 2005). A range of contributions from natural scientists, historians, artists and geographers emphasise the potential value of critical zone(s) as a new spatial vocabulary and mode of spatial practice. Its emphasis on heterogeneity, locality, radical interdisciplinarity and non-binary thinking about the roles and responsibilities of 'science' and 'politics' may make the notion attractive to both critical and applied environmental geographers.

II Zoning science

'Zones' have not been terribly apparent in the spatial repertoire of geographers of science and technology, although many will associate the concept of 'zone' with practices of delineating and segregating urban space (Talen, 2012), or with modes of exclusion and containment in relation to natural or technological hazards (Alexis-Martin and Davies, 2017). Relevant here is Andrew Barry's notion of 'technological zones': these are spaces of compatible technique and procedure where forms of measurement, assessment, qualification and circulation are given increasingly standardised forms (Barry, 2006). Frequently these zones of technological and infrastructural compatibility extend beyond the borders of nation-states, and are co-produced with new spatialities of (geo)political power (Barry, 2001; Koch, 2021). But a technological zone is not a social structure or a disciplinary institution – a zone is rather an 'assemblage that accelerates and intensifies agency [both human and nonhuman] in particular directions, and with unpredictable and dynamic effects' (Barry, 2006: 241).

Writing in the context of critical zones, Etelain (2020) points out that 'zone' comes to us from the Greek *zonnunai*, to gird, and before that from the Sanskrit *junāmi*, to join or link. The word featured in classical literature to describe belts or girdles, as well

as the climatic bands which spanned the earth and defined zones of human habitability, so a 'zone' need not be a space of segregation. Barry likewise stresses that the borders of technological zones should not be taken for granted, but rather interrogated as part of the discursive and material means by which other distinctions – such as between capitalism/non-capitalism, or modern/non-modern – are constructed and contested.

This emphasis on a heterogeneity of spatial forms, agency and relations of mutual dependency means technological and critical zones have much in common. But while technological zones may be defined by the stamp of human technologies, we might query the extent to which critical zones are to be defined by natural science, or perhaps by forms of socioecological systems research. Occasionally, critical zone discourse seems to reinvent collaborative watershed management, offering similar questions of how to integrate social and biophysical data (Curtis et al., 2005) while attending to issues of cultural belonging and political domination at a landscape scale (Steinberg and Clark, 1999). Yet the critical zones 'paradigm' (Brantley, 2020) seeks to go beyond these functionalist modes of environmental management by offering a Humboldtian synthesis of knowledge which spans the sciences, social sciences and humanities, alongside a novel emphasis on long-term, cross-scalar and cross-disciplinary forms of empirical observation (Pierret, 2020).

Through this new empiricism critical zonology points the observatory away from the heavens and back down to earth – the observatory and the field combine, and field sites are made permanent through new, interlinked technologies of measurement and surveillance (cf. Stock and Gardezi, 2021). A critical zone, to be known, must be a metrological zone (Barry, 2006). The emphasis on observation reflects wider calls for a new empiricism – or a new attentiveness (Krzywoszynska, 2019) – in response to the Anthropocene's challenges of complexity, entanglement and unpredictability; an expression of humility counterposed to the 'command and control' logics of previous eras of environmental science and management (Chandler, 2018; Swanson et al., 2015). Nonetheless, high technology figures prominently in accounts of critical zonology, with Aguilar et al. (2020) for example championing the role that drones and machine learning can play in 'anthropogeomorphology'. Thinking with critical zones therefore opens-up a range of pertinent questions to which geographers of science and technology are already posing important answers, including: how do new techniques and technologies of data collection transform social relations? How does interdisciplinarity function in practice? And what are the stakes of being critical about critical zone science and technology?

III From the treetops to the bedrock

Geographies of technoscience are increasingly taking landscapes and biomes like deserts (Koch, 2021) ice sheets (Bruun, 2020) or oceans (Lehman, 2018) as the starting point of analyses, rather than (or perhaps in addition to) the classic spatial repertoire of laboratory or field. Starting from these more-than-human realms reflects a growing concern with how sciences like ecology are implicated in the management, exploitation and protection of environments across an increasingly diverse set of geographies (e.g. De Bont & Lachmund, 2019; Oldfield, 2021; Rodenbiker, 2021), as well as an enduring interest in how science and technology are bound-up with the multiple agencies of the nonhuman world (Roberts, 2017; Salazar et al., 2020). But it also reflects a new interest in volumetric spaces. The verticality of knowledge production, and of technological life, has recently become a key interest of geographers and historians of science and technology (Hardenberg, 2020; Minor, 2020; Pérez, 2015), informed in part by the recent surge of interest in vertical and volumetric geopolitics (Endfield & Van Lieshout, 2018; Lin, 2016; Veal, 2021). Critical zonists likewise urge a re-orientation of spatial perspective in environmental thought, one which emphasises vertical connections between bedrock, soils, biota and atmosphere, thus calling forth new means of environmental visualisation which transcend conventional cartographic practices and their horizontal biases (Arènes, 2021; Arènes et al., 2018).

One such means of vertical observation is drone technology. Drones have attracted much critical

attention for their role in reshaping geographies of surveillance and warfare (Gregory, 2018; Kindervater, 2017) and their place in processes of atmospheric enclosure (Lockhart et al., 2021). Like Lockhart et al., (Garrett and Anderson, 2018) nonetheless draw our attention towards the fundamental ambiguities of drones in geography – they are capable of both 'good' and 'bad', and should offer geographers – both human and physical – not just targets of critique but also new means of knowledge production. Naomi Millner's work on the use of drones by forest communities in northern Guatemala offers useful reminders that the meanings, affordances and destinations of evolving technologies are 'never finally decided' (Millner, 2020:12). Addressing the drone as an assemblage of human and nonhuman agencies and capacities, Millner explores the democratisation of vertical knowledge production in a setting where conservation science and practice has all too often been pressed into the service of state violence and the oppression of indigenous peoples. Drone technologies, which have rapidly colonised conservation practice, are used here to generate new forms of authoritative and yet conflictual knowledges (Brigstocke et al., 2021), such as 'cartographic testimony' to the ecological benefits of existing community forest management practices, which will play a crucial role in the making of new territorial claims. Millner also reflects on how these new practices of technologically mediated knowledge-making foster new forms of human–nonhuman attunement amid a wider ethos of care, expressed for example in the experiences of those seeing their forests from above for the first time: 'the care emerging from such technological entanglements seems to offer rich possibilities for thinking beyond the militarised, securitised and neoliberalised visions of conservation acquiring traction globally' (Millner, 2020: 12).

Venturing underground, Bruun (2020) examines a particular genre of expeditionary science in 1950s Greenland, as the US military sought to reckon with the ice sheet as a new arena of military action. Building on recent theorisations of terrain as a product of negotiation between 'the material agency of the geophysical world' (p182) and forms of calculation and control which make space 'legible for the purpose of political intervention' (p170), Bruun shows how unleashing 'the geopolitical potential of the ice sheet' (p168) depended on new scientific appreciations of the subterranean. Reckoning with the ice as a lively, turbulent, voluminous environment, scientists dug pits, tunnels and trenches to observe its behaviour in time and space, and packaged the subterranean environment in sample boxes and photographs for analysis in distant laboratories. This fieldwork had immediate practical as well as symbolic value – attuning the military to the 'inherent fluidity and the forcefulness of the ice' and thus rendering the ice safe for both crossing and inhabitation, while also conferring political legitimacy through the construction of infrastructural 'emblems of modernity and progress' (p181–2).

This military-scientific engagement with the subterranean world of ice offered new ways of studying past climates and of synchronising human and geological time (Achermann, 2020; Sörlin and Isberg, 2021). Much recent critical attention has been directed towards the spatial practices and imaginations of geology, driven by the evolving debate about the Anthropocene and by advances in feminist science and technology studies (STS) and geophilosophy, with its extension of post- and more-than-humanist thought into the supposedly inert rocky substrate of earthly life (Bobbette and Donovan, 2019; Bosworth, 2017). Significant here is (Yusoff, 2018), who positions the discipline of geology at the heart of a set of ontological ruptures which are central to the planetary transformations of the Anthropocene, but which have heretofore been largely absent from Anthropocene discourse. Yusoff contends that geological modes of thought and practice were co-constitutive with a new mode of dividing the world into the human and the inhuman, the discipline 'a regime for producing both subjects and material worlds' (p4). Into the category of the inhuman were cast assemblages of matter with properties to be newly exploited and exchanged, 'a standing stock of gold, energy, and slaves, organized as they were, as concomitant categories on a bill of sale' (Yusoff, 2018), 71. Geology functioned as a colonial science not just in an instrumental and material sense of turning nature into ownable and exploitable resources, but also in its capacity to give

rise to new subjectivities, not least in the category of the human as one which excluded Blackness. Working with the tools of black and indigenous studies, Yusoff maps out how this 'White Geology' continues to be the privileged episteme of the Anthropocene, continuously foregrounding a universalised but racially coded 'Man' as the main protagonist of this new human story, and erasing or ignoring the histories of brutalised black and brown bodies which are 'the energy and flesh of the Anthropocene', ever excluded from processes of surplus accumulation, and which 'must absorb the excess of that surplus as toxicity, pollution, and intensification of storm. Again and again.' (Yusoff, 2018, 82).

IV Time for critique? Being critical in the critical zone

Barra (2021) develops Yusoff's arguments about the 'geosocial registers' of the Anthropocene in the case of coastal restoration projects in Louisiana. In examining the work of coastal scientists, policymakers and communities fighting for access to land and water, Barra shows how efforts to engineer sediment flows continue long-standing practices of racial violence and marginalisation. The kind of geologic thinking criticised by Yusoff persists into the era of climate change adaptation, as 'the materials and practices that constitute environmental restoration are entangled with racial histories that sustain and indeed sediment racial geographies and their futures' (Barra, 2021: 278). Barra resists the atmosphere of emergency that 'does not leave space (or time) to address…racial histories and injustices', and suggests that 'what can appear as staunch critiques leveraged at scientists and coastal policymakers' can instead be interpreted 'as timely suggestions for…repairing racial and economic inequities beyond a zero-sum game of winners and losers' (Ibid: 278–9).

Barra's work is a reminder that temporal framings of environmental 'emergency' can mobilise action, but they can also obscure ongoing forms of violence and foreclose capacities to become otherwise (Anderson et al., 2019; Whyte, 2018). The urgency of the wider environmental crisis and its iniquitous effects has created a queasiness in some quarters about turning the tools of critical theory or deconstruction onto the geosciences. Latour (2004) famously pondered the implications of STS's deflationary stance towards the sciences' claims to objectivity in an age of accelerating climate change (cf. Butler, 2019), while more recently Andreas Malm (2018) has dismissed 'constructionism' as one of the theoretical edifices which keeps critical thinkers from acknowledging the severity of climate change, and from fully participating in the fight against it. This is not the place to revisit the 'science wars', but Castree (2021) offers a pithy defense of work which queries *how* (rather than *whether*) climate change is constructed, and which interrogates the effects of dominant constructions (like carbon budgets, for instance) on collective efforts to govern the atmospheric commons (see also Machen and Nost, 2021). But the aforementioned studies of science and technology in 'the critical zone' all, in their own way, raise questions about the place and role of critiques of technoscience in a moment of apparently accelerating environmental crises.

The emergence of 'critical physical geography' (CPG) is testament to how geographers have long recognised that interrogating practices of knowledge-making need not be in conflict with a relationship of care towards the objects of that knowledge-making – such as the physical environment or the climate system (Lave et al., 2014; Tadaki, 2016). Stories of critical zone science tend to tell reasonably happy tales of interdisciplinary cooperation and community engagement; reading through *Critical Zones*, power and social conflict is addressed primarily at a global scale, in classically Latourian renderings of dualistic disconnection between 'moderns' and 'non-moderns'. In the CPG literature, power and conflict is engaged with in the local dynamics of geographical knowledge production (Blue & Brierley, 2016), and in the histories of epistemic and socio-material domination and struggle which are increasingly being connected-up with accounts of the biophysical makeup and transformation of landscapes (Colucci et al., 2021).

The work of geographer Max Liboiron and the Civic Laboratory for Environmental Action Research (CLEAR) has modelled an explicitly anti-colonial form of scientific practice, based on the premise that science can only either work with or

against colonial power relations; there can be no neutrality (Liboiron, 2021; see also Cohen et al., 2021). By combining field and lab toxicology (Liboiron et al., 2019) with contributions to STS and human geography debates on toxic politics (Liboiron et al., 2018), CLEAR's work offers a radically different vision of what critical zone science could look like. Relatedly, Colven and Thomson (2018) offer climate modelling as another site where collaboration between human and physical geographers could transform and democratise knowledge-making. They suggest that a CPG approach could help address the well-documented problems of spatial abstraction in climate change science (e.g. Hulme, 2010), bringing climate science back down to earth by integrating knowledge of local social and biophysical processes, particularly those that elude the parameterisations of climate models or the scopic regimes of remote sensing. As such, CPG could be one way in which geographers could intervene in the politics of scale in science (Finnegan, 2015), and in the kind of knowledge geopolitics described by (Meehan et al., 2018). In so doing, geography might prefiguratively build the kind of social contract for global change research advocated by Castree (2016) – one that is overtly political, intellectually plural, and organised around new senses of the responsibility and accountability of research (and researchers) in building democratic and decolonial futures (Wright and Tofa, 2021).

Such a project is as urgent as the environmental crisis itself. The wider social contract of science has been put under severe strain since (Castree, 2016) intervention, most notably in countries where right-wing populist and proto-authoritarian governments have openly attacked the social credibility and material infrastructures of scientific work (Miguel et al., 2019; Walker et al., 2018). The Environmental Data and Governance Initiative (EDGI), founded in response to the election of Donald Trump, is an intriguing instance of how critical geographers and STS scholars have navigated the new politics of environmental knowledge. While theoretical descriptions of science as 'situated knowledge' may be interpreted as a deflation of science's claims to absolute objectivity, Dillon et al. (2019) draw on feminist STS to argue that it is possible to defend science from political attack without subscribing to simplistic realist epistemologies, nor by defending the liberal regulatory state as an ideal mode of political order. In developing the notion of 'environmental data justice', they explore how data rescue projects can move beyond the preservation of the technical artefacts of the liberal state towards practices of data stewardship which actively build new and inclusive communities of concern, oriented around an ethics of care for data, for each other, and for threatened communities and environments (see also Wylie et al., 2017). In so doing, they argue for expanding political ecology's 'traditional focus on toxic exposure to include questions of data stewardship, the politics of technical infrastructures,' and the emancipatory potentials of novel coding tools (Dillon et al., 2019, 552). There are important connections here with critical GIS, which likewise seeks to imagine and enact new forms of politics through 'counter-data' and 'counter-mapping' (Burns et al., 2018), and of course to the emergence of 'digital geographies' as a new subfield (Kinsley et al., 2020).

V Fixing the future

An ever-growing area of geographical literature has productively brought together critical studies of technoscience with that of infrastructure, natural resources and political ecology (Barry, 2013; Bosworth, 2018; Klinger, 2017). Recent work has examined technologies and infrastructures like waste incinerators, bioenergy and wind energy as spatio-temporal or socioecological fixes for emerging crises of capital accumulation, within the context of changing regimes of environmental regulation and energy production. Ingrid Behrsin has argued that existing literature on renewables as socioecological fixes has not openly 'questioned how scientific knowledge claims propel certain types of technologies and energy sources to be classified as renewable' in the first place (Behrsin, 2019: 1362). Bringing together political ecology with literature on neoliberal technoscience, she offers a revealing analysis of the strategically ambiguous formulae by which waste incineration is classified as renewable under European Union regulations, thus opening up cross-

border trade both in solid waste and carbon credits. Collectively this literature points towards the emergence of new, overlapping and often globe-straddling technological zones, wherein flows of matter and energy are rendered newly legible, calculable and fungible, and are thus ontologically transformed: municipal waste is remade as an internationally mobile energy commodity (Behrsin 2019); forests of the US South are transformed from 'carbon sinks' to 'high throughput carbon conveyors' for European biomass plants (Palmer, 2020); the subterranean is transformed into a resource frontier through the global circulation of new, standardised geoscientific and geo-metric techniques (Kama and Kuchler, 2019).

Much of this work has been informed by an expanded conception of 'labour' in political-economic thought, whereby the creation of value is seen as dependent on 'unpaid work done by living systems' (McCarthy, 2015: 2488). A new emphasis on nonhuman labour (Krzywoszynska, 2020) and lively capital (Barua, 2020) draws our attention to how segments of the critical zone are not just being colonised by human technologies for the purposes of accumulation or rational management, but are, through the purposeful enrolment and direction of nonhuman labour, themselves rendered a technology of planetary maintenance and modification (e.g. Palmer, 2020).

For instance, Kevin Surprise positions planetary geoengineering as the ultimate spatiotemporal fix to capitalism's second contradiction. Efforts to modify planetary albedo expand the atmospheric waste sink and thus delay the realisation of climate change as the ultimate manifestation of capitalism's propensity to engender systemic crisis through environmental degradation (Surprise, 2018; see also Yusoff, 2013). Likewise, Wim Carton has written persuasively of how so-called 'negative emission technologies' (NETs), which produce energy while pulling carbon out of the atmosphere, function as a spatiotemporal fix that defers the devaluation of carbon-intensive accumulation processes (Carton, 2019).

This work is indicative of a range of engagements by critical geographers, of various theoretical orientations, with as-yet-non-existent technologies and their place in the politics of envisioning, imagining, materialising and contesting futures (e.g. Asayama et al., 2021; Cusworth et al., 2021). Such future technogeographies range from the nakedly imperial (Surprise, 2019) to the prefiguratively decolonial (Gergan and Curley, 2021), and are increasingly important sites for geographical engagements with efforts to 'fix' the critical zone; or rather efforts to use the critical zone as a spatiotemporal fix for contemporary capitalism. As technologies like NETs increasingly start to 'touch down in space and time', as Behrsin (2019: 1374) puts it, moving from spaces of experimentation to deployment and producing inevitably uneven geographies 'of risk and reward' (Gergan & Curley, 2021), there is much to keep geographers busy. Yet while aversion to apparent 'techno-fixes' for the socio-political crisis of climate change can come naturally with a critical disposition, Markusson et al. (2017) argue, like Buck (2019), that it is nonetheless possible to conceive of more just and egalitarian worlds being helped into being by technologies which are commonly bracketed as 'geoengineering'. The work of geographers of technoscience in the critical zone(s) of the Anthropocene thus needs to be as imaginative as it is critical (Braun, 2015), generative of new visions of future technogeographies and of the kinds of socioecological worlds they might summon into being.

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Note

1. See also Tsing et al.'s (2019) articulation of a 'patchy Anthropocene.

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