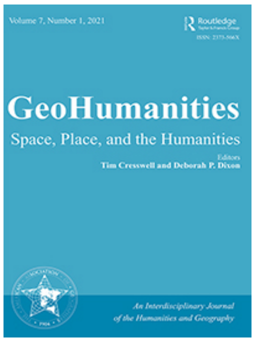

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MONSOON ASSEMBLAGES FORUM

Sedimentary Ways

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This paper is a thought experiment to attune to the geo-physical and geo-political materialities of sediment, a *terra-aqueous* substance produced when the earth's continental surfaces intra-act with the atmosphere and are chemically transformed by it. The paper is framed by questions of how to engage more closely with the dynamics of earth systems and of how social and political agency emerges alongside earth forces. Sediment is important to such questions because it is the mechanism by which the earth recycles itself and is thick with the climatological and geological histories that have conditioned the possibility of life on the planet. While acknowledging the import of Deleuze and Guattari's metaphysics to such questions, the paper takes a material approach to them. It is based on field work in Bangladesh, but also traverses a range of scientific, historical and theoretical literature. It is arranged in four sections that loosely correspond to the sedimentary cycle. It follows sediment from chemical processes on rock surfaces in the Himalayas, to its lively travels in monsoonal rivers across flood plains to its eventual deposition and subterranean diagenesis. In each section, the paper discusses the material processes at work, their socio-political enmeshments and the theoretical implications of these intra-actions. The paper concludes that sediment serves as a reminder not only of close entanglements of geo-physical and geo-political becomings, but also of the profound indifference of earth systems to human affairs, and asks what this might mean for the re-imagination of politics. **Key Words: matter, monsoon, politics, sediment.**

In their introduction to the special issue of *Theory Culture and Society: Geosocial Formations and the Anthropocene*, Clark and Yusoff (2017, 3) argued that for some time "most social thought has taken the earth to be the stable platform upon which dynamic social processes play out." However, they continued, contemporary climate change and the Anthropocene are prompting social thought to engage more closely with the dynamics of earth systems and to consider how social and political agency are constrained, made possible, interact with and emerge alongside earth forces. This echoed Grosz's (2012) call to think through rather than about the earth and to afford political power to "the elemental forcefulness of the earth itself" (Clark 2017, 223).

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In this paper, I respond to this call by thinking through the ontologies of sediment. By sediment, I refer to the material produced by the decomposition of rock strata by the atmosphere. Sediment is what happens to rock strata when they are exposed to and chemically transformed by the atmosphere and carried by air, water or technology elsewhere. Whereas strata have been taken up by political geographers (e.g. Braun 2000; Bridge 2013; Clark 2017; Elden 2013; Mitchell 2011; Yusoff 2017), sediment is under-theorized, but offers as much to geopolitical theory as strata do. For one, it shifts thinking about strata and politics from layers to molecules, bringing Deleuze and Guattari's (1987) concept of strata into conversation with their concepts of the molar and the molecular (Deleuze and Guattari 1987; Guattari 1984; Guattari and Rolnik 2007). I read Deleuze and Guattari's molar and molecular to be distinct but overlapping "abstract machines" (Deleuze and Guattari 1987, 213) at work in all geo-physical and geo-social collectivities. Molar modalities are clear cut or calculated arrangements that construct "rigid lines of segmentarity" (Deleuze and Guattari 1987, 195) whereas molecular modalities develop transitory "segmentations in progress that are defined by quanta of deterritorialization" (Adkins 2008, no page). In Deleuze and Guattari's thought, the two organizational modes do not oppose, but complement one another, intermingling and overlapping (Guattari and Rolnik 2007). The stronger a molar organization is, the more it induces a molecularisation of its own elements and relations, though these molecular combinations can leak out and elude molar assemblages, if only to return to reshuffle their segments and escape in lines of flight again (Deleuze and Guattari 1987). Deleuze and Guattari thus use the molecular as a figure of becoming. "All becomings are molecular," they write, "the animal, flower, or stone one becomes are molecular collectivities, haecceities" (Deleuze and Guattari 1987, 275). The molecular articulates "processes of movement—of being in-between, of the interstitial that escapes the confines of the definition of a subject or object" (Davis 2016, 207).

The association of the molecular with states of becoming has enlivened debates in the fields of mobility studies, nonrepresentational and affect theory. McCormack (2007) argued that questions of the molar and the molecular are not questions of materials or scale, but rather questions of the materiality of relations, forces and rhythms. He considered the molecular to be a "field of distributed and barely tangible forces" operating at the threshold of perception (Deleuze and Guattari 1987, 281), from which "sensible economies of experience emerge" (McCormack 2007, 372). Merriman added to this, arguing that the molar and the molecular are not distinguished by size, scale or substance. They are modes of becoming distinguished by their "perceptibility, representational legibility, mode of organization, consistency and 'segmentarity'" (2019, 68). He associated the molar with what is "easily represented or expressed" and the molecular with movements that are "vital, incessant and unruly, operating below the threshold of perception" (2019, 67). This move displaced binaries such as mobility/immobility from studies of the geographies of mobility (see e.g. Adey 2006; Cresswell 2010, 2014) by adopting a more "radically processual" approach (Merriman 2019, 70). While thus alerting mobility scholars to the play of molecular movements, affects and forces within and across molar geographies, Merriman unwittingly fell back into precisely what he critiqued, namely "realist approaches founded on binaries and dualisms" (Merriman 2019, 68). For what are perceptible/imperceptible, representable/nonrepresentable if not binaries, and do they not reinforce realist perspectives of perception and representabilty, leaving questions of to whom, at what scale, with what means, under what conditions etc., unanswered (see Haraway 1991)? In summary, these thinkers follow Deleuze and Guattari in denying the molar and the molecular materiality other than as force. In doing so, they, at worse “sneak back in a metaphysics of life projected onto inorganic matter” (Gamble, Hanan, and Nail 2019, 112) or, at best, transform matter into nothing other than relations of force (Bennett 2010). The molar and the molecular become metaphysical powers either separated from material substances, or the substances from which “bodies, materials, sensations and worlds emerge (Merriman 2019, 69).

This is precisely not the framing that I use in this paper. Instead of a radically processual approach to sedimentary ontologies, I take a radically material one. I use the materiality of sediment as an ontological analytic of politics. I take clues from Sutherland’s (2013) critique of the metaphors and metaphysics of flow, fluidity and flux as the substance of today’s globalized world (Castells 2010). Sutherland argued that this way of thinking “obscures the situated materiality and substantiality of individual actors (human and non-human) within the world” (Sutherland 2013, 9) and makes it difficult to identify potential sites for political praxis within it. In this vein, Ingold polemically pitted “materials against materiality” (2007, 1), to discount the discourse of materiality as a mental construct that intimates a social world that is “ontologically distinct from the material realities of external nature” (Ingold 2007, 3). Ingold proposed instead that materials are the active constituents of a world-in-formation and argued for the merits of performative, relational engagements with materials and their worlds. This brought him into conversation with Barad’s (2007) performative approaches to scientific knowledge production, with their co-implication of ontologies and epistemologies (Gamble, Hanan, and Nail 2019).

In this paper, I think sediment as an ontological category of monsoonal mattering. I approach sediment not as an abstract molecular/molar machine, but as terra-aqueous molecules in motion, or, to avoid confusion, as particles of terra-aqueous matter in motion, where size, scale and substance matter. Here the paper lies closer to the work of elemental geographers such as Nieuwenhuis (2018) on sand, Whitt (2018) on mud, Gustafson (2015) on landslides and Peters (2015) on the ocean, rather than to the work of molecular/molar theorists. The paper is kin to follow-the-thing methodologies (Appadarurai 1986; Marcus 1995) which, though usually applied to consumer goods along supply chains (Cook 2004; Gregson et al. 2010; Hulme 2015) or traveling cultural products such as policies (Peck and Theodore 2012; Roy and Ong 2011) and data (Akbari 2020), have also been used in earth system work, such as in Acciavati (2015) on the Ganges River and Cullen (2020) on clay bricks. In this paper, I investigate how sediments form, travel and settle, following them from the Himalayas to the Bay of Bengal. I track who or what they meet along the way and political disputes they provoke or become entangled with. The sites I traverse with them are made up not only of physical locations and field sites, but also of scientific papers, historical accounts and gray literature. The journey is not continuous, but partial, incomplete and full of gaps, and the paper more of a speculative storytelling that a comprehensive survey. What it offers is an interdisciplinary method for rethinking territory and, to invert Cresswell (2010), not the politics of mobility, but the materiality of politics. For sediments mobilize surfaces and materials, unsettle dry, grounded notions of place and undercut binary notions of geo-physical and geo-political worlds. They remind us that the earth’s cycles and matterings are lively, elemental, entangled and emergent, extend our understanding of intra-actions between elements, bodies, space and time, and open the trajectories of human life and struggle to the long *durée* of planetary cycles.

In his paper Politics of Strata, Clark (2017) quotes from stratigrapher Zalasiewicz’s description of the earth as “a gigantic machine for producing strata” (2008, 17). Its mechanics are driven by the “churning currents of magma in the inner earth” (Clark 2017, 213) powered by the radioactivity of the planetary core, and by the earth's atmospheric and hydrological cycles that are propelled by incoming solar energy (Zalasiewicz 2008). Produced by intra-actions between the earth's coupled systems—the lithosphere, the biosphere, the hydrosphere and the atmosphere, strata and strata forming processes are the forcefulness through which the earth renews itself and life and politics unfold (Clark 2017; Grosz 2012; Yusoff 2017). Sediment is both the outcome and the lubricant of these processes.

The word sediment comes from the Latin word *sedere* to sit and *sedimentum*, meaning a settling or sinking down. This etymology ties human conceptions of sediment to its alluvial and lithifying moments. However, sediment has a far more dynamic life-story than this. From its formation in chemical laboratories on rock surfaces to its deposition by turbidity currents in deep oceans, sediment is characterized by movement and ongoing trans-corporeal exchanges with its environment. It rests, sometimes for millennia, but, even in resting, its molecules are intra-acting with each other and their surroundings. Sediment is the earth's warehouse and its liveliness. Sedimentologists tell us that while sedimentary rock comprises only about five percent by volume of the terrestrial crust, it makes up eighty to ninety percent of the earth's surface and contains its entire store of groundwater and fossil fuels (Zalasiewicz et al. 2008). It serves as testament to the earth's history (Derry and France-Lanord 1997; Raymo and Ruddiman 1992; Vogeli 2016; Yusoff 2017) and, increasingly, to human interference with it (Zalasiewicz et al. 2008). As Carson (1950[1989], 77) put it, "sediments are a sort of epic poem of the earth. When we are wise enough, perhaps we can read in them all of past history."

The chemistry, size and shape of sediment particles, how they move, what they wash up against and for how long and when and where they settle, all matter to those who live on, in or alongside them. To misquote Clark on strata, sediment is "as much a propellant and provocation of social life as it is a resource to be used or an object of control (Clark 2017, 223). Sediment is an agent of world making and all life is positioned in the midst of its formation and deformation:

> that slender province where the immense energy of incoming solar radiation converges with the upwelling forces of the earth's radiative core, a critical zone where volatile and erosive forces are ceaselessly weathering older exposed strata and sedimenting them into fresh layers. And this means that all human habitation of the earth, even when it doesn't entail circumnavigation or other excursions, is a kind of journey—a passage through the multi-scalar rhythms, singularities and thresholds of a planetary surface in motion. (Clark 2017, 228)

The paper is presented as part of Monsoon Assemblages, an ongoing research project on the monsoon in South and Southeast Asia, where sediment is mobilized in vast quantities each year and matters a great deal to those whose lives are entangled with it. It fertilizes fields, is molded into embankments or platforms for habitation, is transformed into building materials and provides protection from rising sea levels. However, its volume and the forcefulness of its movement is volatile, threatening and often destructive (Cette vidéo traite de Evenements Ladakh 2010) and human engagements with it are shaped by politics. In the paper I follow sediment from its formation on disintegrating Himalayan rock faces, to its transportation by monsoonal rivers, to its deposition on alluvial flood plains and coastal deltas, to its ongoing transformation in geological strata. The paper is arranged in four sections—weathering, saltating, alluviating and lithifying that correspond with the stages of this journey. At each stage, I discuss the material processes at work, their socio-political entanglements and the theoretical implications of these intra-actions. The paper is based on field work in Bangladesh, where I traversed rivers thick with sediment, witnessed the precarity of life on *char* islands, observed the technologies of dredging, sand pumping and brickmaking and conducted interviews with, amongst others, dredgers, political activists and planning officials. A range of literatures and sources were consulted and integrated into the text. These include scientific literature on sediment and sedimentary processes, texts on sediment management and on the history of embankment building in British India, anthropologies of char island life and gray literature and critical texts on the arsenic contamination of ground water. The data informing the paper is thus a patchwork of information drawn from multiple, diverse sources which have been integrated into an account of sediment as a transformative material and a dynamic, terra-aqueous provocation of socio-political life.

WEATHERING

> The surface of the land … is made by nature to decay … Our fertile plains are formed from the ruins of the mountains. (Hutton 1788[2010], 7)

I begin my story of sediment in the Himalayas, the mountain range that that stretches for 2500 kms from Afghanistan in the west to Myanmar in the east. There is disagreement as to when the Himalayas were formed, but most scientists concur that around 50 Mya, the Indian tectonic plate, which had been nudging northwards from Gondwana since about 120 Mya, began to collide with the Eurasian plate. The Tethys Ocean that had intervened between them was closed, its oceanic crust was subducted under the Eurasian plate and the northern continental margins of the Indian plate were thrust upwards to form the Himalayas (Raymo and Ruddiman 1992; Vogeli 2016). The Himalayas are made up of four parallel litho-tectonic units, the highest of which is crystalline rock, with the others made up of sedimentary rock, volcanic rock and ophiolites, all of which are the remnants of previous sedimentary cycles or tectonic events (Vogeli 2016). The mountains form a physical barrier to cold air masses from arid central Asia moving southwards and moist, warm air of the south Asian monsoon moving northwards. While the main driving force of the Himalayas is the ongoing Asian-Indian convergence, it is the monsoon that plays a major role in its weathering and erosion (see Figure 1) and, some would argue, in the tectonic process itself (Allen and Armstrong 2012).

Weathering, as understood by geologists and geomorphologists, is a process of rock degradation through intra-actions between mineralogy and the weather (Davis 1899; Pope, Dorn, and Dixon 1995; Zaharescu 2020 and others). Zalasiewicz (2008) describes weathering as an intimate, slow, chemical intra-action between rock crystals and the atmosphere. The earth's crust, he tells us, was formed when primordial earth rock (igneous rock) crystallized out from the earth's molten state billions of years ago (see too Carson 1950[1989]). Its molecular structure was formed at high temperatures and pressures in the earth's interior. Once thrust upwards by tectonic forces, cooled and exposed to the atmosphere at the earth's surface, its silicate mineral structure forged at high temperatures and pressures, becomes unstable, disintegrates and reassembles into minerals more suited to their cooler, wetter surroundings (Gupta 2012; Merriman 2002; Zalasiewicz 2008). Hydro-chemical intra-actions are the prime agents at work in this process, but temperature change and plant life play their parts too. Temperature variability may cause rocks to expand and contract, resulting in thermal stresses that open up cracks and fissures; water seeping into these cracks may freeze and expand, widening cracks

FIGURE 1 The Himalayas from the Leh-Manila Highway along the Indus River, July 2018. Photograph by and permission from Harshavardhan Bhat.

and opening them to further dissolution. Where plant life takes hold, it may not only tear open or widen fractures and cracks, its roots are chemically active—they extract mineral ingredients from rock, which further weakens its structure (Dontsova, Balogh-Brunstad, and Chorover 2020; Foye 1921; Welland 2009).

The weakest links in the chain of these processes are the most common silicates in the earth's crust, feldspar crystals (Welland 2009). When exposed to the atmosphere, feldspar transforms into tiny flakes of silicon, oxygen and aluminum ions that grow from solution on the surfaces of pores and fractures in the rock, "as in a chemical garden" (Zalasiewicz 2008, 21). The floating ions combine into clay minerals such as illite and kaolinite, which are acidic and serve as further weathering agents (Keller 1947). Quartz, another common silicate has stronger crystals than feldspar thanks to its interlinked tetrahedra of silicone and oxygen atoms. As feldspar decays around them, support for quart crystals vanishes and they drop out of their source rocks as grains of sand (Welland 2009). This corrosive chemistry may extend far below a rock's surface, penetrating down discontinuities such as faults and joints, themselves a record of a rock's tectonic and climatic history. The interface between chemically weathered rock or regolith, and un-weathered or sound rock, forms a well defined, though contingent and moving boundary that geologists call a "weathering front" (Phillips, Pawlick, and Samonil 2019, no page). Just as meteorologists call the boundary between high and low pressure systems in the atmosphere weather fronts, so the front lines of weathering in rocks are called weathering fronts. This means that, far from being external to the earth and its rocks, the weather extends deep within them, in some places to depths of tens or even hundreds of meters (Ollier 1988).

Scientists use the term rotting, a term usually associated with the decay of animal or vegetal matter to describe these processes (Welland 2009; Zalasiewicz 2008). If this is so and rocks rot too, the distinctions between organic and inorganic matter, between life and non-life start to fall apart. This observation supports Povinelli's (2016) contention that such distinctions are not found in nature, but serve to bolster the boundaries of liberal democracies and the edifices they are built on, "as an allegory for nature stilled into resource" (Cohen 2015, 11). The image of rocks as living, lichen covered, expanding, contracting, cracking, trans-corporeal, intra-active "weather bodies" (Neimanis and Walker 2014, 558) is a far cry from the image of solid, unyielding stone with which rocks are commonly portrayed. It exposes the anthropocentric bias of phrases like "as solid as a rock." For, while in relation to the time of a human life and human perception, rocks might seem solid, from longer and closer perspectives, they are not stable or solid at all. They are lively, decaying, rotting, transmogrifying weather bodies, just like, albeit different from our own. "Stone might itself be a kind of organism" wrote Cohen (2015, 126).

Weathering processes operate slowly and at microscopic scales controlled by many variables such as the mineralogy of the parent rock and its weathered products, the micro-topographies of rock faces and the variables of climate measured at the scale of the "micro-climate that prevails at the sub-millimeter hydraulic boundary later" (Pope, Dorn, and Dixon 1995, 43). Such micro-climates and the chemistry they foment are nevertheless inextricable from and emergent with the tropospheric climate. Because rock weathering draws CO_2 out of the atmosphere, it plays a central role in regulating the carbon cycle (Walker, Hayes, and Kasting 1981) and engages in tight, complex feedback loops with climate change (Dosseto et al. 2015; Raymo and Ruddiman 1992). Because of this, scientists are today experimenting with turning weathering into a resource to slow climate change (Beerling et al. 2018), which will inevitably make it a new site of political issue formation. Weathering is a conceptual and practical tool for understanding the "inner worldings of the world" (Davis 2016, 208) and for reframing human relations with the earth. Vannini, Waskul, and Gottschalk proposed that "to weather is, in short to dwell" (Vannini, Waskul, and Gottschalk 2012, 362), highlighting the mutually constituting, performative, nonrepresentational relations between weathering and dwelling. Neimanis and Hamilton (2018) also suggest that by moving beyond the idea of the weather as background to life and thinking of weathering as the common space and co-joined time of bodies and places, we might begin to understand the intra-active processes of mutual becoming through which life and weather materialize and come to matter. Weathering, they argue, is "a particular way of understanding how bodies, places and the weather are all inter-implicated in our climate-changing world" (Neimanis and Hamilton 2018, 80).

SALTATING

Once freed from their middle-earth molecular strictures, particles of sediment join the weather, so to speak. They are transported away from their source rocks by gravity, water and wind (Foye 1921). As tiny mountains in transit, they enter an environment of aero- or hydro-dynamics in which they are forced to suspend their rocky assumptions and the security of knowing what will happen next (see Figure 2). They move in their transportation medium by saltation (McGee 1908). This is not a commonly used word. It comes from the Latin *salire*, to leap and *saltare*, to dance. It describes how, whether dragged along a surface or held in suspension in turbulent eddies of air or water, sediment particles bounce, jump, leap, roll or tumble along (Parsons, Cooper, and Wainwright 2015). They become terra-aqueous particles of matter, barely distinguishable from the dynamics and characteristics of the fluids that carry them. Geologists describe what transpires when sediments saltate as a complex interplay between particle substance and size, fluid velocity, gravity, slope, channel width and depth, bed surface and so on (Gilbert 1914). The physics of these processes is chaotic and emergent (Church 1996). At low fluid velocities, sediment particles roll downstream, staying in contact with the bed-surface. Here the forces exerted by the fluid on the particle are only enough to roll it along. As the fluid velocity increases, its drag and lift forces may become sufficient to lift sediment particles against gravity from the surface, in a trajectory "analogous to that of a cannon ball" (Gilbert 1914, 28). Particles are accelerated by the fluid, but pulled downward by gravity at the same time, causing them to travel in roughly ballistic trajectories (Gilbert 1914; Kok et al. 2012). If a particle has been sufficiently accelerated by a fluid, it may bounce up again and eject or splash other particles in saltation, which propagates the process further (Bagnold 1941). A particle might also disintegrate on impact or eject much finer sediment from its surface. In air, this process is known as saltation bombardment, and creates most of the sand in sand storms (Shao 2008). Sediments are thus not only transported by saltating, they are

FIGURE 2 Saltating sediments held in suspension in the Ayeyarwaddy River, Bagan, Myanmar, September 2019. Photograph by the author.

reshaped by it. Their roundness, size, chips and angles record not only their mineralogical origins, but also their journeys and the knocks and bumps they receive along the way. They are transmogrified in turbulent intra-actions with the fluids that carry them, in turn transforming fluid velocity, viscosity and shear stress, and the materiality, width, depth and gradient of the surfaces they are transported over.

In describing the dance of sediments, scientists use militaristic terminology such as ballistic trajectory, projectile, cannon ball, bombardment and so on (Bagnold 1941; Gilbert 1914; Kok et al. 2012). Saltation is a mode of mobility in which fluid velocity transforms sediment particles into little missiles set against and reshaping each other and the environments they move through. This mobility carries with it the potential for violent territorial and social disruption. In Bangladesh it can result in sudden, ruptures known in Bengali as *chapa banga, banga* or *hanria banga*.

> *Chapa banga* literally means the breaking of the bank in *chaps* (chunky portions) and occurs during the rainy season when the rivers overflow in swift currents … *Banga* or the breaking of the soil can wipe our large pieces of land—from one to two acres—in a matter of minutes. The breaking is often preceded by a sound that can be heard from a distance and the formation of large rings of circular water currents called *ghurnis* that loosen the soil along the bank walls and make them slide immediately. *Hanria bhanga* means the breaking away of the soil as if it is a clean sweep down to the bottom of a *hanri* (a round cooking pot). In *hanria bhanga*, the strong, speedy and sharp undercurrent of the river cuts through the soft, sandy layer and reaches two to three kilometers inland from the bank. (Lahiri-Dutt and Samanta 2013, 40–41)

These ruptures produce what is known in Bangladesh as “the land of Allah *jaane* (of God only knows)” (Baquee 1998 in Lahiri-Dutt 2014, 24), where sediment heavy rivers braid or shift, creating precarious, nomadic units of land called chars. Chars are transient, mobile assemblages of geo-hydrological matter-energy that form and reform in seasonal monsoon rivers each year, at times emerging or disappearing without notice. They cannot be mapped, legally owned or recorded in revenue papers because they move around too quickly and too frequently. Chars have historically been occupied by precarious, marginal populations, “as fleeting as the lands they inhabit” (Lahiri-Dutt 2014, 24), often those without official documents. Those who live on them have no choice but to dance with the river (Lahiri-Dutt and Samanta 2013) and lead perilous, calamitous lives (Chatterjee no date). When the monsoon breaks and the flow of rivers increase each year, their land frequently deserts them, their shelters are devastated, crops are damaged and livestock washed away. As the river recedes, new chars emerge and fierce, at times violent struggles to occupy them ensue. These are overseen by local strongmen who exert unquestioned authority over the distribution of land, and subject char dwellers to subservience (Feldman and Geisler 2013; Lahiri-Dutt 2014). Saltation plays out into clientalist, almost feudal political relations and is key to understanding this world in its violent becoming.

In thinking about the mobility of weathered sediments, I am indebted to Peters’s (2015) paper Drifting: Toward Mobilities at Sea, in which she drew from Cresswell (2010) to examine drifting as a mode of oceanic mobility, responding to questions of what drifting is, who or what drifts, how and under what conditions and what it means and how it feels to drift. This extended the concept of mobility beyond human mobility to the material energies of the ocean and human interactions with it and unlocked knowledge of the earth beyond that of *terra firma*. I suggest that the dance of sediments extends similar insights to our understanding of terra firma itself. Here Steinberg's (2011) introduction of Lagrangian fluid dynamics to the discussion of oceanic space is helpful. Lagrangian and Eulerian are alternative models of fluid dynamics that come with alternative spatial ontologies. The Eulerian model measures and models fluid dynamic forces acting on stable points by assuming that the stable points are external to the mobile forces that act on them. The Lagrangian model on the other hand is based on particles and how they move, defining movement as "the displacement across space of material characteristics within mobile packages, not abstract forces," and that "these characteristics are known only through their mobility" (Steinberg 2011, 273). In Lagrangian fluid dynamics, "objects come into being as they move (or unfold) through space" and "space ceases to be a stable background but becomes a part of the unfolding," suggesting a spatial ontology "constantly being made by its dynamic constitutive elements" (Steinberg 2011, 273). Thus the ocean, Steinberg argued, "is not a world of stable places that are impacted by moving forces. Rather, in the ocean, moving matter constitutes places, and these places are specifically mobile" (Steinberg 2011, 272). I suggest that in the great monsoonal river basins of the world the spatial ontology of ground itself is Lagrangian. It is far from fixed or stable, but is reorganized and regenerated each year by the hydraulic solid-liquid vitality of the monsoon and the weathered sediments it transports. To dwell there, humans are required to tune to and work with the earth in its fluid becoming (Alaimo 2012). Places emerge as ever changing constellations of performative relations between bodies, materials and geo-physical forces. Some of these assemblages are stable for long periods of time, others are incessantly reforming. Some, like mountains, are fairly stable, but may suddenly be transformed by the build up of tension within them (McPhee 1980) and a river course may be relatively fixed at one scale, but move dramatically at others (Church 1996). Adam (1990), Serres (1995) and Massey (2006) all highlight that places and climates are crossed by a whole range of scales, rhythms and temporalities. Some take shape within realms of human experience, agency and comprehensibility, others respond to events utterly beyond human capacities to experience, impact or even think them, from the "imperceptibly fast to the unimaginably slow" (Adam 1990, 165). Sedimentary river basins remind us that humans have little mastery over these complex processes, which have the "fearsome capacity" (Clark 2011, xvi) to undo sustaining human connections and footings without notice. Yet humans are implicated within them, intra-actively made and unmade within these emergent material ecologies, some of which their actions transform.

ALLUVIATING

To alluviate is a transitive verb, meaning to cover with or to deposit alluvium. It comes from the Latin noun *alluvius*, derived from *alluere*, meaning to wash against and to leave traces of that material exchange behind. The word deposit on the other hand has connotations of value and safe-keeping and deposition is a legal term referring to informal, extra-judicial evidence. Alluvial deposits carry all of these meanings. They are assemblages of earth matter washed over and deposited on topographic surfaces that carry evidence of their origins and transportation history (Ramesh et al. 2000) and are valued for their fertility and regenerative value (D'Souza 2009). Alluviation is an intra-active material exchange between fluids, sediment and soil that redistributes the rubble, sand, silt, clay and organic matter that a river has gathered from multiple elsewheres and othertimes, the more varied the sources, the more fertile the results.

According to Serres (1995), recounted in Elden (2013) Cohen (2015) and Clark (2017), the alluvial moment in the geological-hydrological cycle of the Nile River was when humans first transformed the geophysical into the geopolitical by transforming the materiality of fluvial deposits into territory, science and the law. Serres told this story of the birth of territory:

> Given normal weather, the Nile's floods submerged the borders of tillable fields in the alluvial valley fertilized by the great river. At the return of low water, royal officials called *harpedonaptai*, who were surveyors or geometers, measured anew the land mixed with mud and silt to redistribute or attribute its parts. Life got going again. Everyone went home to get back to work. (Serres 1995, 51)

According to this account, the concept of territory and its associated civil, private and fiscal laws arose from the need to recalibrate human society with the deposits of the annual flooding of the Nile River. This alignment was achieved not by splitting soils and fluids into discrete domains, but by sciences of measure that merged with the watery deposits of the retreating Nile, so that "as the Nile ebbed, the husbandmen followed the retreating water and scattered their grain over the slime and ooze" (Willcocks 1930, 3). Thus human society was calibrated with flooding and its deposits and, something Serres failed to mention, ties the birth of territory to the seasonal dynamics of the east African monsoon.

The Ganges, Brahmaputra and Meghna Rivers and their tributaries drain the southern part of the Himalayas, part of Tibet and the Shillong Plateau across the vast low lying coastal plains of Bangladesh to the Bay of Bengal. They discharge 8,000 m^3 per second of water in the dry season and 120 000 m^3 per second in the monsoon season, along with an estimated 1,000,000,000 metric tons of sediment each year (Jakobsen, Azam, and Mahboob-ul-Kabir 2002). The dynamic ebbs and flows of these rivers and the sediment they transport intersect with oceanic tides to produce a "shifting environment of soil and water, alluvium deposits and migrating river systems" (Kierantimberlake 2014, no page). Within this "hydrological lattice work," the "ambiguity of habitation" (Kierantimberlake 2014, no page) means that people have always had to manipulate the flows of tides, rivers and their sediments to survive (D'Souza 2009). Historically in villages in the Ganges and Damodar delta, networks of broad, shallow canals tapped silt laden flood waters, diffusing silt over agricultural fields and allowing "the annual inundations to actively function as geomorphic agents which, through time raised the land and thereby blunted the ferocity of flood currents" (D'Souza 2009, 19). With similar logics, current practice in the Ganges delta is not only to build embankments to protect from flooding, but also to make controlled embankment breaches to allow fluvial and tidal sediments to maintain ground levels inside them (Auerbach et al. 2015).

In Dhaka, Bangladesh's capital city, different performative engagements with sediment have emerged since the early 2000s as the city grew and ruling civil-military elites turned to real estate to consolidated their economic power. Dhaka is a magnet, driven by its economic dynamism, climate change induced migration and Bangladesh's centralizing administrative policies (Bird et al. 2018). The city lies at the southern tip of the Madhapur Tract, a geological outcrop of relatively firm ground elevated above the low-lying, flood-prone deltaic plain. After independence from Britain in 1947 and later from Pakistan in 1971, the city grew rapidly in a northerly direction along the Madhapur Tract, constrained by low lying flood-prone land to its east and west. After unprecedented flooding in 1988, a western embankment was constructed; encircling part of the floodplain, it opened up the western side of the Madhapur Tract for development. The embankment soon became a spine of urbanization and land prices on either side of it skyrocketed (Bird et al. 2018). No similar measure was taken on the eastern side, which remained a low-lying zone of wetlands, retention ponds, waterways, agricultural villages and paddy fields (Ashraf 2017). As the city's population grew and the central and western areas filled up however, land availability diminished and prices rose. In order to address this, RAJUK, the Dhaka regional planning authority began reclaiming 6,000 acres of land to the east of the city to develop into a new town called Purbachal to house 1,5 million people, and built a massive 300 ft wide road connecting it with west Dhaka. From 2002 onwards this infrastructure began to open up east Dhaka for private real estate speculation (Tribune Desk 2019). The processes involved two modes of territorial transformation. In the first, agricultural lands were seized, often violently (Ali 2017; Sarkar 2019) and their levels raised by three to twelve meters by pumping a sediment rich slurry over them (Bird et al. 2018). In the second, public canals, rivers and wetlands were illegally privatized by filling them with dredged sediment, often by or with the collusion of public authorities (Ali 2017, 2019; Feldman and Geisler 2013). Companies deployed fleets of barges, dredgers and trucks, thousands of hydraulic pumps and kilometers of tubular piping (see Figure 3) to transform grassy turf, ponds, wetlands, canals and paddy fields into vast, white platforms of sediment (Mould 2019; Sarkar

FIGURE 3 Sediment pumping on the Turag River in East Dhaka, October 2019. Photograph by the author.

2019). They acted with impunity, despite high court injunctions brought against them (Islam 2019; Staff Reporter 2019). The real estate so created was then sold, often fraudulently (Islam 2019) and developed into middle class housing, industrial estates, university campuses, mosques, shopping malls, hospitals and so on.

In one sense, there is nothing new or novel about this. It is common practice in Bangladesh to raise buildings on mounds or plinths of sediment to elevate them above the flood plain. What is new however is the acceleration of this process through capital intensive technologies of dredging and pumping and the links of these technologies to cronyism, consumption and the market. Under these conditions, the "liquid matter" of sediment (Ashraf 2017, no page) provides the infrastructure for urbanization and serves as an instrument of erasure and social and environmental injustice (Ali 2017, 2019). In most cases the hydrological performance of the territory is ignored, or, as Neimanis and Hamilton put it, the whims of water are muted (2018, 80). This does not just raise questions of clogged drains and water-logged streets during the monsoon, as important as such questions are, but rather of how urbanizing a floodplain without any consideration for the social, environmental or hydrological consequences of doing so might play itself out in the long term.

LITHIFYING

To lithify, from the Ancient Greek *lithos*, or stone, is a verb meaning to convert or be converted from unconsolidated sediment into rock. Like the other sedimentary processes, lithification, or diagenesis as it is scientifically known, as a vital, intra-active process of physical and chemical change that takes place as sediment is subject to subterranean pressure and temperature (Jackson and Bates 1997). Once sediments are buried, overlaying layers compact lower layers, slowly squeezing out their water content and decreasing their porosity. Chemical and/or structural changes to sediment surfaces, the fluids between them and any organic matter buried with them occur as overburden and temperatures increase (Merriman 2002; Milliken 2003). The edges of grains may dissolve into solution; minerals or dissolved ions may precipitate on the surface of grains and solidify, eventually cementing the grains together; a mineral may decay and change into another mineral or its chemical composition may stay the same, but its crystalline structure may change (Milliken 2003; Welland 2009). Which of these takes place depends on the redox potential of the solution i.e. the potential for electrons to be transferred between its solutes (Williams and Freitas da Silva 2006). Heat and pressure similarly transform organic matter buried with sediments into fossilized hydrocarbons. Peat is transformed into coal by residual moisture being squeezed out of it, and phytoplankton, algae and other organisms are transformed into simple lipid molecules, the main ingredient of crude oil. Over millions of years, lipids are changed into complex molecules called kerogens, which humans apply heat to to transform into petroleum and natural gas (Ourisson, Albrecht, and Rohmer 1984). These lively physical and geochemical process at work at various depths in the stratified earth have produced its stores of breccias, sandstones, mudstones and limestones, its iron and aluminum ores, its aquifirs and its fossil fuels.

Interactions with stratified compositions have long played a constitutive role in social and political life and as "sites of political issue formation" (Clark 2017, 214). In Bangladesh, subterranean engagements have focused on aquifirs, and, to a lesser extent on hydrocarbons

(Detsch 2014). Underneath Bangladesh's topography, Pleistocene and Holocene sedimentary deposits, recharged each year by annual monsoon rains, form one of the most productive aquifer systems in the world (Kinniburgh and Smedley 2001). In the 1970s the newly established Bangladesh Water Development Board (BWDP), guided by the United Nations Development Programme (UNDP), began the study of these underground water deposits, spurred by the United Nations Children's Fund (UNICEF)'s mission to assist developing countries to access clean drinking water. Finding large quantities of ground water at shallow depths, Bangladesh, working with international agencies, then began a campaign to promote the use of shallow, hand-pumped wells for the extraction of drinking and irrigation water (see Figure 4). So successful was this campaign that over the next twenty years, six to eleven million wells were drilled across the country (Kinniburgh and Smedley 2001), giving ninety seven percent of the population access to microbiologically safe drinking water (Ahmed, Khan, and Haque 2018). Then, in 1993, arsenic contamination of ground water was discovered in the west of the country. Subsequent studies showed that an estimated forty to sixty million people had been exposed to arsenic contamination and the World Health Organization (WHO) declared the ingested contamination to be "the largest poisoning of a population in history" (Smith, Lingas, and Rahman 2000, 1093). Educational programs urged people to access safer water and contaminated wells were marked with red paint, but little was done to tap cleaner supplies and many people had no option but to carry on drinking contaminated water (Loewenberg 2017).

FIGURE 4 Man using a hand-pumped well in the Rangabali Upazila, Bangladesh, November 2011. Photograph by the author.

Arsenic is present in most of the earth's rock, though recent research suggests that concentrations are found in magmatic arcs where tectonic plates collide (Mukherjee et al. 2019). Most sediments deposited in Bangladesh come from high altitude magmatic rocks in the Himalayas or from granites and metamorphic rocks on its south and central slopes (Kinniburgh and Smedley 2001). These include particles of ferrous oxide chemically bound with arsenic. In the sluggish anaerobic conditions of tropical marshes and swamps in Bangladesh and West Bengal, the ferrous oxide particles, stable at cold, high altitudes, break down and their arsenic is released and seeps into the ground water (Loewenberg 2017). This molecular decoupling does not occur uniformly across the country, only in young alluvial and deltaic Holocene sediments, and with highly localized variability both vertically and laterally. Neighboring wells in a village may have different concentrations, as might wells at different depths and a well that was uncontaminated might become contaminated over time. These differences reflect variations in sediment characteristics and the liveliness of subterranean hydro-geological regimes, revealing that the underground is a complex four dimensional environment of nothing but change (Kinniburgh and Smedley 2001).

Once ingested in drinking water, arsenic works as a "tasteless, odorless, pernicious poison" (Loewenberg 2017, no page) by de-activating the enzymes that transport energy around the body (Ratnaike 2003). After ten years or so skin pigmentation on the chest and skin lesions on the palms of the hands and soles of the feet become visible. Over longer periods, the poison might cause skin cancer and internal organ pathologies, such as lung or bladder cancer and cardio-vascular disease (Ahmed, Khan, and Haque 2018). Its slow, creeping violence (Nixon 2011) inter-implicates bodies with "the thickness of geological and climatological time" (Neimanis and Hamilton 2018, 81) by extending subterranean hydro-geological processes deep into body cells. However, it does so selectively, within an already socially differentiated world. In Bangladesh, arsenic poisoning impacts male agricultural workers in economically deprived communities with poor nutrition more than others (Loewenberg 2017). They work long hours in the hot sun, drink a lot of water and rely on rice, which also takes up arsenic, as their staple diet. Their exposure is enhanced or mitigated by their relations with local patronage networks who control access to clean water wells along familial, caste or political lines. Subterranean processes are thus inscribed in bodies in ways that reinforce the systemic violence of a socially, culturally and politically differentiated world.

CONCLUSION

This paper has been a thought experiment to attune more closely to earthly processes and to develop a sense of the ways in which their dynamic, intra-active, material exchanges have socio-political lives. It has responded to Elizabeth Grosz's call to think through rather than about the earth and to afford political power to "the elemental forcefulness of the earth itself" (2012, 973). The paper has explored ways in which human bodies, relations and politics are constrained and constituted by mobile ontologies of sediment. It has followed sediment materially as an ontological category of monsoonal mattering, made, unmade and remade at particular sites by multiple temporalities of geology, weather, technology and politics. From the chemical alchemy that produces sediment on the surfaces of Himalayan rock faces, to its lively displacement in monsoonal torrents, to its deposition on the flood plains of Bangladesh and transformation in subterranean or sub-oceanic environments, human politics and ways of being-in-the-world are caught up in, shaped and reshaped by sedimentary processes, which they in turn transform. The precarity of living in such environments is highlighted by Spivak, who, in reference to those who inhabit the flood-prone coasts of Bangladesh wrote: "They build in the expectation of obliteration … they grieve and want relief, to rebuild in the face of certain loss, yet again" (Spivak 1995, 154 in Clark 2011, 207). Their lives embody Deleuze and Guattari's figure of the nomad, "the one who does not depart, does not want to depart, who clings to the smooth space left by the receding forest … and who invents nomadism as a response to this challenge" (Deleuze and Guattari 1987, 381). What is important here, as Clark (2011) reminds us, is that it is the earth that does the moving as much as the agents who dwell on it, and that the nomadic response to stay in place is by no means conservative, it is engaged and experimental.

Sediment serves as a reminder not only of the close entanglement of the geo-physical with the geo-political in their becomings, but also of the profound indifference of dynamic earth systems to human affairs (Clark 2011). Stone, wrote Cohen "would be on the move even without us" (2015, 126). Yet while we are moving with it, it is best to be mindful that our lives are intermeshed with it (Alaimo 2018) and there is no possibility of barricading, containing, or sealing ourselves off from it. Being attentive to sedimentary ontologies and their life worlds requires a re-attuning to "the multi-scalar rhythms, singularities and thresholds of a planetary surface in motion" (Clark 2017, 228) and to the entangled relations we have with the geological world around and inside us. However, its liveliness and multiple temporalities and rhythms pose real problems for politics (Clark 2011; Massey 2006), questions taken up, in part, by Latour (2004) and Stengers (2005) with their idea of cosmopolitics—for Latour, a politics of contest, deliberation and negotiation to assemble and administer the world that we share with heterogeneous, shifting, human and nonhuman others; for Stengers, how to incorporate earthly forces that we live in intimate relations with yet are inimical and entirely indifferent to the questions we pose them, into our conception of politics and life itself. Thinking cosmopolitically is about acknowledging our constitutive, collective vulnerability to the earth and its rumblings and finding ways to deal compassionately with those exposed to its eventfulness.

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