Extraction in four dimensions: time, space and the emerging geo(-)politics of deep sea mining.

Introduction: of time and the sea(bed)

It is anticipated that in 2019, the deep seabed will be commercially mined for the first time. Nautilus Minerals, a Canadian mining company is, in its own words, 'leading the world in the quest to develop seafloor mineral deposits' (Nautilus 2015a) as it prepares to extract high grades of copper and gold from the Pacific seabed in the territorial waters of Papua New Guinea (PNG) at the 'Solwara 1' deposit. Inspired by the imaginaries of the adventure novel[1], a spirit of exploration and discovery is culturally ascribed to the imperatives of capitalist expansion. In doing so, the emergence of deep sea mining (DSM) is thus conceptualised by some commentators as a new 'resource frontier' - an 'edge of space and time' in which nature 'appears inert: ready to be dismembered and packaged for export' (Tsing 2003: 5100) – or as a 'commodity frontier' where 'further expansion is possible so long as there remains un-commodified land[…]"beyond"' (Moore 2000: 412). Globally, national governments and corporations are moving to facilitate DSM as a viable industry[2] where their efforts to explore and commodify metals, minerals and phosphates imagine the activity as spatially bounded by a very particular 'frontier' or border zone - the deep seabed itself.

However, DSM's contemporaneity as a legal-political issue invites engagement with a new kind of geopolitics, one which moves beyond classical concerns with inter-state relations and which draws upon recent trends in critical social science and theory. In the first instance, this means moving beyond state centred concerns with territorialising the surfaces of the planet, and the associated 'flatness' and fixity of their geopolitical imagination. Indeed, more progressive recent accounts have urged us to reconceptualise subterranean geopolitics and its strategies as projecting downwards, upwards and outwards to a more three dimensional and voluminous world (Elden 2013; Bridge 2013). Secondly however, and more provocatively, this paper argues that future engagements with the geopolitics of DSM need to go yet further in thinking beyond this spatially recalibrated sense of geopolitics and include a fourth dimension, *time*, more centrally into its analysis.

The temporalities of DSM are as multi-dimensional and immanent to this novel framework for extractive geopolitics as are their (still important) spatialities. These may be projected forwards; DSM's target metals and minerals have been constructed both historically and currently as 'resources of the future', global finance is courted by corporate pronouncements of DSM's 'resource potential', 'waste' from the extractive process is included in predictions of environmental impact and so forth. But the temporal also engages with the geological time of deep-sea topographical formation; for example, where hydrothermal vents form at very different speeds to deep-sea polymetallic nodules, or where the status of resources can be either materially altered by physical forces such as volcanism or through discursive shifts inspired by (human) knowledge production and

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[1] 'The Nautilus' is the submarine in Jules Verne's classic, 19th century science fiction novel *20,000 Leagues Under the Sea*.

[2] For example, in addition to PNG's permission to allow DSM extraction to begin, the UK government passed the Deep Sea Mining Act in 2014, which aims to enable state-sponsored support for emergent UK DSM companies.

commodification. Taken together, studies of DSM geopolitics need to move beyond erstwhile accounts of deep-sea mining that have been generally situated in descriptive narratives of marine science, environmental law and (uncritical) geopolitics. Whilst these perspectives all have plenty to offer in describing DSM's complexity and challenges, they do so without properly connecting political ecological understanding with the political possibilities produced by taking dynamic nature and its systems seriously.

Even though the state border still remains a vital threshold for realist geopolitics, both in general terms and for DSM, I argue that political issue formation for DSM is more accurately generated by a meeting of this classical geopolitical thinking with the political possibilities produced by the four dimensional actions of the underwater world itself. This includes the multiple spatial and temporal registers through which both the geology and ecologies of seabed and seawater operate. Doing so opens up a different constellation of critical thresholds in which earth systems and the materiality of the deep seabed and the deep sea is taken seriously. What roles, might one ask, do the properties, forces and dynamics of the deep seabed play in the emergent politics of varied DSM practices?

The answers are, of course, varied but always rest on understanding the shifting temporalities of deep-sea resource making[3]. This means that at times, it is the fluidity, voluminosity and dynamism of the sea and seabed that matter in shaping DSM's geopolitical possibilities. At other times however, the geological processes of the ocean floor and its topology can move so slowly as to be inert, obdurate, even disconnected, or bounded. Being attentive to these geophysical and scientific properties is essential for understanding the contemporary geopolitics of DSM because it does crucial work in explaining how the metals and minerals of the deep-sea come into being and are 'made' into resources. Thus, the version of geopolitics presented here seeks to extend the burgeoning literature from resource geographies concerned with a material turn (e.g. Bakker and Bridge 2006, Lehman 2013, Li 2014, Valdivia 2015) by drawing upon recent, cognate efforts from resource anthropology (Kama 2013, Richardson and Weszkalnys 2014), including nascent analyses of resource temporalities (Weszkalnys 2015). From this perspective, deep-sea mineral resources 'become' political by being 'constitutive of and constituted within arrangements of substances, technologies, discourses, and the practices deployed by different kinds of actors' (Richardson and Weszkalnys 2014: 16).

The article proceeds by first outlining the different types of DSM, noting their different volumes, mineralogy and geographies. It then sets out a framework for conceptualising a geopolitics of deep-sea mining. This begins by setting out an overview of the various political forces that are shaping the contemporary debate on DSM and shows how they are quite distinct from terrestrial mining practices and materialities. These range from the capitalist impulses from corporations and their sponsoring states to the anti-DSM narratives generated by environmental groups and proximate island communities[4]. As resource extraction and oceanic space become coupled more intimately

[3] A much fuller description of the deep-seabed's mineralogy is offered in the following section.

[4] In Papua New Guinea, for example, anti-DSM campaigners such as the 'Alliance of Solwara Warriors' are campaigning and resisting corporate-led DSM Activity by connecting island groups across the Bismark Sea where the Solwara 1 project is proposed. These local forms of collective action are, in turn, connected to more global social movements such as the 'Deep Sea Mining Campaign' which is based in Australia but draws upon a global network of activists. Such resistance is important for understanding the emerging geopolitics of DSM both in terms of its efficacy and its dynamics. However, because of the present paper's focus around DSM

than ever before, the complex modes of governance required to legislate for DSM's human actors are intertwined with questions of the seabed's unique remoteness, materiality and relative invisibility. Important though these power assemblages are, it locates them in a literature which has centred around the geologic politics of the anthropocene, one which is mindful of thinking about the relational politics of resource spatialities and temporalities. Following this, it presents its key argument – that critical theories of new extractive geopolitics hinge upon recognising more fully the importance of their temporalities as well as their spatialities – by developing an extended series of examples from the embryonic DSM sector, particularly the Solwara 1 site in Papua New Guinea. These examples are drawn from areas of contention around which DSM political issue formation has clustered such as law, technology and economic development. There are doubtless more, but they all concern the tension between resources conceptualised as relational on the one hand and the ontological fixity of human political choices on the other. In each case, examples operate both spatially *and* temporally: where the subterranean is not solid but porous, where the deep geological time of mineral formation is captured only at its very moment of becoming circumscribed as a resource and where matter changes state between molten rock, liquid water, mineral rich gas and precipitated ore. The article concludes by highlighting the possibilities for future (critical) geopolitical formations for DSM, reminding us that it 'is open to political interventions, not a matter of foregone conclusions' (Dalby 2015: 47). The geopolitics of extraction in extreme places, is not only spatially complex, it is also a matter of time.

Types of deep sea mining

Deep sea mining is extremely diverse. On the one hand, new commercial interests coalesce around a number of overlapping interests including exploration, mapping, sampling, logistics, not to mention the extraction of potential mineral deposits. On the other hand, the deposit types themselves also vary considerably across their geology, mineralogy and their depth. Taking 'depth' as a key variable, most definitions of DSM focus on three major categories of deposit; seafloor massive sulphides (SMS), polymetallic nodules (PN) and cobalt rich crusts (CRC). These are summarised in Table 1 below. It should be noted that although other types of marine extraction (such as diamond and phosphate mining) are in varying stages of development[5], these occur in much shallower waters and are not considered in this paper. Instead, the three types of DSM outlined here are composed of different combinations of metals and minerals. At a simple level, the composition and concentrations of these various deposits coincides with an increasing global demand for more metal and mineral resources, one that is driven by the imperatives of economic growth, consumption and manufacturing. Examples of these are analysed later in the paper but the prevalence of conventional metals such as copper and gold deviate from rare earth metals and cobalt as they become variously written into or out of classical geopolitical narratives of 'security of supply' and 'discovery'.

Table 1 also describes how both the depth of different deposit types and the level of volcanic activity on the seabed floor vary dramatically and this has significant implications for the sorts of technology that emerge. The extreme pressure and the geologic violence of volcanism (the Solwara 1 SMS deposits in PNG are within 3 kilometers of the highly active volcano 'North Su') shapes both the

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temporalities, a detailed analysis of these political actors is reserved for future work emerging from the broader research project.

[5] Many mineral deposits can be found offshore on the shallower continental shelves of the planet. They have been mined for tin (in Southeast Asia), diamonds (Namibia), gold (Alaska) and marine phosphorite, a potential source of fertilizer, occurs everywhere from Namibia to New Zealand (Hannington et al 2017).

articulations of risk and the political geography of the infrastructures built to support DSM activity. Depth also impacts upon the mineralogy of deposits in the case of CRCs - with the highest concentrations found in the shallowest waters. As the International Seabed Authority (ISA) - the global regulator of mining activity in the area beyond national jurisdictions – states, this is likely to be 'an important factor for exploitation' (ISA 2017) given that extraction tends to be easier and cheaper at shallower depths. For CRCs, many of these shallower, more viable occurrences are situated in exclusive economic zones of the south and mid-Pacific (such as the Marshall Islands, Hawaii and Micronesia) bringing them into dialogue with the obligations of economic development narratives and policies of the future.

Table 1: Types of deep sea mining and some selected characteristics

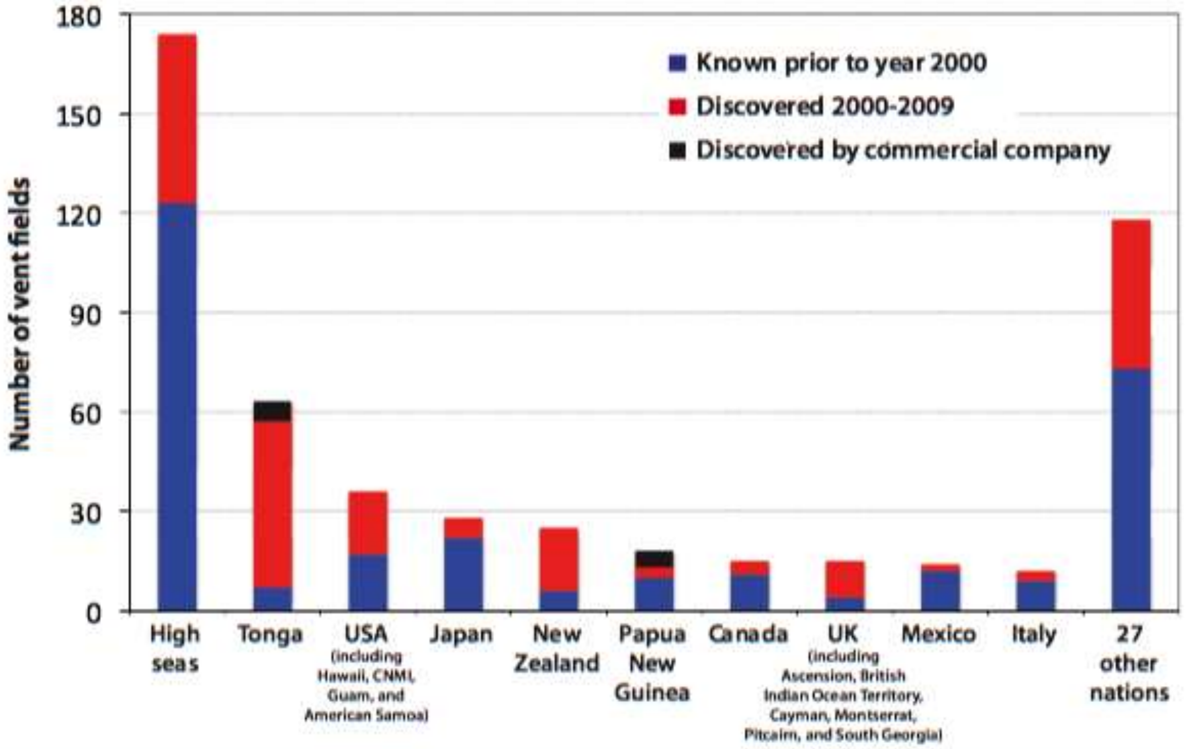
		Deposit Type		
		Polymetallic Sulphides (SMS)	Polymetallic nodules (PN)	Cobalt-Rich Crusts (CRC)
Important Factors	Geologic description	• Formed at boundaries of tectonic plates through interaction of 400°C magma and seawater • Mineral rich fluid discharged through hydrothermal vents (Active and inactive)	• Found on abyssal plains of oceans • Minerals form into potato sized shapes (5mm-10cm in diameter).	• Forms metal rich crust on flanks and summits of seamounts. • Often situated in areas that are very steep
	Speed of geologic formation	• Precipitation of sulphides leads to 'chimney' formation. Very rapid growth and re-growth (following collapse or mining) – up to 1ft in 2 days (Gwyther and Wright 2008)	• Form very slowly (about 1inch per million years)	• Thickness of crust varies (1-260mm) depending on age of seamount but 2-6mm per million years (ISA 2017)
	Major associated metals	Copper, Zinc, Gold and Silver	Manganese, Iron, cobalt, copper, nickel, rare earth elements	Cobalt, also iron, manganese, nickel, platinum etc.
	Depth (metres)	400-4100, majority between 1400 and 3,700 (Boschen et al. 2013)	3000-6000, mostly 4,500-5,500	400-7000, mostly 1000-3000
	Global distribution	• Found globally, usually along mid-ocean ridges. • Type of deposit found at Solwara 1, Papua New Guinea (world's first commercial extraction site)	• Usually outside of Exclusive Economic Zones (EEZ) • Greatest concentratio n in Clarion	• Often in EEZs of island states of the South Pacific • Over 11,000 seamounts in the Pacific Ocean alone

			Clipperton Zone, an area off the West coast of Mexico, 80% size of the contiguous states of USA (Wedding et al. 2015: 144)	(Yesson et.al 2011)

The three deposit types also exhibit profoundly different spatialities and temporalities and these matter in the geopolitical formations that emerge. For example, the geographical distribution of SMS deposits is such that the hydrothermal vents and their metalliferous chimneys tend to cluster close together, often in particular national jurisdictions (see Figure 1 below). These chimneys may grow at different rates and be different ages but they are mostly small enough to be extractable within a time frame significantly shorter than that of a typical terrestrial mine. For example, the Solwara 1 deposit is only 0.1sq km and will take only 2-3 years to exhaust. Polymetallic nodules, by contrast, vary in their level of clustering from dispersed to concentrated where they may be touching each other. Although both forms of DSM occur globally, a map of global exploration, drilling and sampling activity[6] reveals a preponderance of vessels active in the waters of the mid-Atlantic (in the case of PN deposits) and the South Pacific island states (in the case of SMS). Furthermore, the incidence of different DSM types varies dramatically: Only 19% of the commercially viable area for PNs lies within the EEZs of coastal states. This compares with a significantly larger '42% of the favourable areas for SMS and 54% for CRCs being located in EEZs' (Petersen et al. 2016). Such clustering serves to 'provide a material record of the economic and political conditions in which they were made, and the corporate and national strategies they were designed to achieve' (Bridge 2009: 45). Nowhere is this better demonstrated than in PNG, where, despite its long and troubled histories of terrestrial mining projects and their impacts (Kirsch 2014), DSM's approval by the state is facilitated by regulations only slightly adapted to the country's erstwhile Land Mining Act.

[6] See Deep Sea Mining Watch (2017) for an interactive cartographic representation of DSM activity globally.

Figure 1: Number of active hydrothermal vent fields per national jurisdiction



(Source: Beaulieu et al. 2010)

Finally, the geologic speed of deposit formation profoundly varies between the different types. These contrast dramatically from the extremely fast (up to one foot of mineral rich chimney growth every two days in the case of SMS deposits) to the inordinately slow (the formation rates of both PN and CRC are amongst the slowest geologic processes on earth). This variability has two implications for the sorts of geopolitics that might emerge from DSM activity. In the first instance, it asserts the importance of resource temporalities just as much as their spatialities. This suggests that it is not just the variable 'quality of underground space' and its mineral concentrations that 'provide massive ecological subsidies to modern[…]life' (Bridge 2009: 43). Also important is the notion that those 'subsidies' are temporally compressed at vastly different speeds; the material and discursive processes of extraction 'makes' resources in a relative instant, spatio-temporally reworking either the dynamism of SMS deposits or the million-fold slowness of PNs and CRCs. Secondly, the comparative *lack* of dynamism associated with PN or CRC formation serves to remind us that when introducing the materiality agenda into questions of the geopolitical, sometimes it is nature's obduracy and not its movements that become most interesting. Despite the undoubted complexity and array of life (the bio-political) in and around the deep seabed, the temporal registers of its geologic (the geo-political) composition and formation can be quite different indeed, vacillating between the dynamic and the fixed.

Conceptualising the geopolitics of deep-sea mining: from human to non-human actors

In this section, I set up a framework for thinking about what kind of geopolitical formations might emerge from DSM. I begin in part a) by detailing some of the key human political forces at play which include efforts to regulate DSM through particular legal regimes. I then move beyond these more classical concerns of geopolitics by locating a framework grounded in the geopolitics of the Anthropocene, which has sought to consider the provocations wrought by the conceptual and material convergence of earth systems and humanity. I then focus the framework by drawing upon scholarship that has moved beyond the erstwhile terrestrial bias of geopolitics to focus on the agency, ontologies and politics of the ocean. Finally, I engage with recent work from political geography and anthropology which has sought to reconfigure the spatial aesthetics of resources (and their political control) by focusing not only on three-dimensional volume (rather than area) as a guiding principle but also upon a fourth dimension - time. Taken together, they go some way to thinking through the shifting assemblages of DSM's geopolitics, one that is at once inclusive of the spatialities and temporalities of geologic movement, its shifting states of matter, and the new political economies of resource extraction.

a) Legislating for DSM's human actors

Across corporate, national and supranational spheres, the economic case for DSM largely rests on a response to international demand for 'critically strategic' metals and minerals albeit articulated in different ways. For example, the latest publically available annual report for Nautilus Minerals clearly states that because 'the ocean contains the largest known mineral inventories on earth' it ('rather than land') best responds 'to contributing towards the global supply of critical minerals while also providing substantial environmental and social benefits' (Nautilus 2015b: 5). For national governments, metals and minerals to be extracted through DSM methods are interpreted as a key part of the resource 'security' debate, whereby the supply of resources (and the halting of their acquisition by other states) becomes part of a series of 'sovereignty games' (Hannigan 2016). This more realist-form of geopolitics sees regional, rising and traditional powers making claims to sovereignty over ocean space for the purpose of DSM and echoes the better-known recent examples of political posturing over resources in the South China Sea (Kaplan 2014) or the Arctic (Dodds 2010). The UK government's *Resource Security Action Plan* (DEFRA 2012) exemplifies this position by asserting the need for amplified extraction from both new and existing geographies. It also foregrounds the 2014 *Deep Sea Mining Act* which aimed to simultaneously allow the government sponsorship of DSM contractors whilst tightening up environmental compliance with the ISA's regulations. By framing DSM as foundational to future resource 'security', it legitimises its role as key to future facing sustainable development strategies. 'Securing' these resources becomes another emerging political technology used to script DSM's emergence as a political object in much the same way as 'energy security' has been shown to normalise political practices of calculation, control and appropriation (Bridge 2015).

According to the conventional geopolitical narrative, DSM is a 'necessary' response to an increased global demand for metals and minerals required for the increased consumption of consumer electronics and future low-carbon infrastructures. Minerals found on the sea-bed are, so the argument goes, higher in grade (quality) than their terrestrial equivalents, have less of a human impact and are key to ensuring that future needs are met. This is particularly the case in European states where the 'security of supply' for rare earth elements (REEs) is seen as essential in a market monopolised by China (Houses of Parliament 2015). Such politicisation of REEs is not new and is always historically contingent (Klinger 2015), yet DSM's proponents are capitalising on the deep-sea's unique environment to discursively rework it as more sustainable than land-based mining for those same elements. For example, a huge tellurium deposit (a key element used in solar panels) has just been discovered in the crust of a seamount close to the Canary islands which alone represents one twelfth of the total global supply. As the lead scientist from that expedition asks 'if we need green energy supplies…we either dig them up from the ground and a make a very large hole or dig them from the seabed and make a comparatively smaller hole' (Shukman 2017).

These supposed ecological advantages of DSM are offset by high degrees of uncertainty regarding its environmental impacts and despite 26 exploration contracts having been granted since 2001 (Wedding et al 2015), there currently remains only one commercial licence to extract – the Solwara 1 SMS deposit in Papua New Guinea, contracted by Nautilus Minerals. Against this background, there are repeated calls for DSM's regulatory regime to be tightened (Van Dover 2011), positioning DSM at a threshold of law, where the legal governance of deep ocean space is said to be 'an ongoing project' (Hannigan 2016: 52). Most attempts to trace the roots of the ideology of marine territorialisation centre on the 17th century debate between proponents of '*mare liberum*' (most notably Hugo Grotius) and advocates of '*mare clausum*' (particularly John Seldon)[7]. In the case of the former, the seas and oceans of the planet were viewed as free (or a 'common possession') to all because they 'are not a thing, not an object of our will…and therefore not property' (Milun 2011: 87). In the latter position, the seas could 'be lawfully possessed by states' precisely because they 'were susceptible of legitimate enclosure' (Selden 1652 cited in Milun 2011: 87). The legacy of these debates for the following three centuries was the related idea that that freedom of the seas (and its use) should prevail 'as long as the rights of others were not hindered' meaning that, in essence, 'sovereignty was only recognised for a narrow belt of sea along the coast: more of less three miles' (Schrijver 2008: 202).

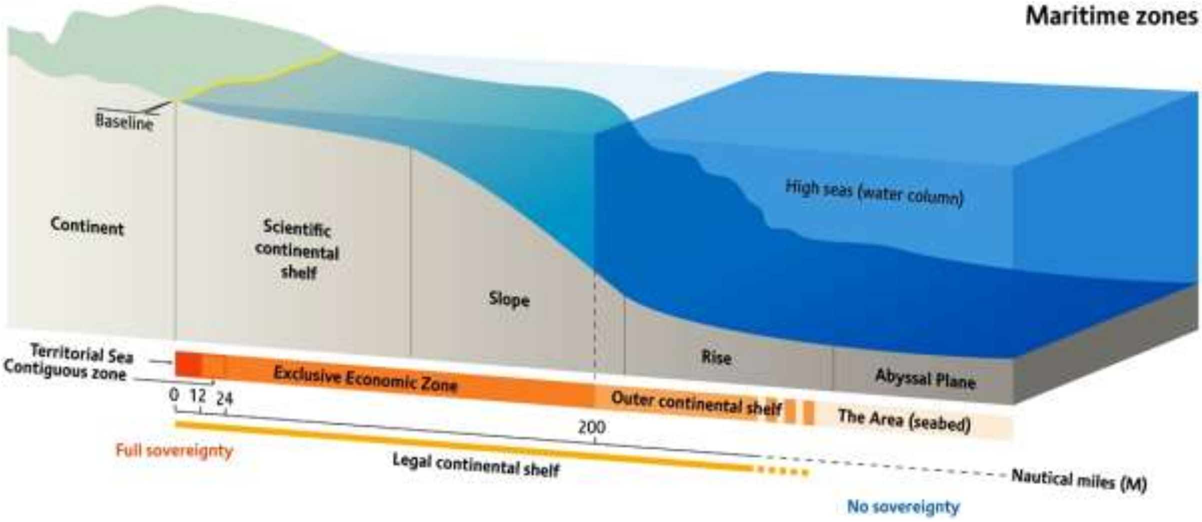
Contemporarily it is the United Nations Convention Law of the Sea (UNCLOS) which guides the regulation of ocean space. Following decades of false starts and protracted negotiations, in 1982 UNCLOS vastly extended territorial sovereignty over maritime space, in part through the establishment of 200 nautical mile wide exclusive economic zones which include the water column, seabed and below (see figure 2). At that time, Article 136 of UNCLOS introduced a key principle: that 'the Area and its resources are the common heritage of mankind' (UNCLOS 1982). In this definition, 'the Area' is 'the sea-bed and ocean floor, and the subsoil thereof, beyond the limits of national jurisdiction' (Article 1) and its 'resources' are 'all solid, liquid or gaseous mineral resources in situ in the Area at or beneath the sea-bed, including polymetallic nodules' (Article 133a). Despite its contemporary originality, many critiques of the convention have emerged which have centred on the fact that it was established at a time when many subsequent technological and scientific developments were not imagined (e.g. bioprospecting) and with the assumption that polymetallic nodules were the only commercially viable type of DSM (Borgese 1998).

At the time of writing, a preparatory committee is consolidating recommendations for the UN general assembly in 2018 in order to influence a new, final treaty on the deep-sea. Topics being addressed include marine genetic resources, area-based management tools and environmental impact assessments (Danovaro et al. 2017). However, they don't include the extraction of minerals from areas beyond national jurisdictions; that, as a consequence of UNCLOS, falls under the remit of

[7] For a fuller explanation of the history of the law of the sea as it relates to marine resources, see Schrijver 2008: 202-230.

the International Seabed Authority. Many of the legal shortcomings of regulating DSM emerge because of the lack of integration between regulatory bodies. This has led to the most recent proposed solutions to deep-sea legal strategies being 'ecosystem based' in which 'more holistic knowledge and monitoring' is required (Danovaro et al. 2017:453). Such formations are based on upping levels of scientific knowledge production, data monitoring and political transparency - in other words all sorts of political technology - which can be read as attempts to 'secure the volume (Elden 2013) in the deep-sea. One example of this is in French Polynesia where 'the complex perimeter of proposed DSM activities and impacts' are defined by a 'politics of time – anticipation, monitoring, adaptability, sustainability – and the politics of space' (Le Meur et al 2016). In short, the demands on effective legal governance for DSM are growing fast but they will be shaped by the spatio-temporalities of the human and nonhuman, by the biopolitical and the geopolitical.

Figure 2: Maritime Zones and Sovereignty under UNCLOS



(Source: Pravettoni, R. UNEP/Grid-Arrendal 2009)

b) Conceptualising a four-dimensional geopolitics of DSM in the Anthropocene

Recent work on the geopolitical formations of the Anthropocene has sought to (re)highlight humanity's role as 'physical actors in the physical systems of the earth' (Serres 1995: 18). Despite a broad spectrum of debate – between the Anthropocene's positive (e.g. Ackerman 2014) and negative (e.g. Kolbert 2014) implications – this scholarship shares a concern with the intersecting futures of technology, humanity and earth systems. These future possibilities are likely to be revealed not so much in a geographically even and just sense, as in an unruly, messy, perhaps 'ugly' series of political interventions and resistances (Dalby 2016). One obvious source of this 'ugliness' is likely to coalesce around the politics of resource extraction given the industry's material and economic status as a geomorphological shaper of earth systems. DSM, through the metaphorical and literal disruptions brought about by its capitalist imperatives, provokes new and unstable examples of this kind of geopolitics. It does so not only because it can be shaped by the relations between humanity and an active seabed and deep ocean (Lehman 2013). It also defies simple classification as a sub-surface phenomenon: on the one hand the seabed is a site of extraction that is a ‘surface of earth’ below a ‘surface of water’. Yet those ‘surfaces’ are defined amongst other things by their permeability and relationality: sea water moves through the seabed, meets magma from below and then continuously shifts forms between mineral rich gas and solid deposits as it settles in the water column. Because these ‘objects’ of extractivism circulate dynamically, the deep-sea is an assemblage of (political) forces which are defined by both their (3 dimensional) spatiality and their (fourth dimensional) temporality. It is an environment where particular ‘elements are drawn together at a particular conjuncture only to disperse or realign, and the shape shifts…according to place’ (Anderson and Macfarlane 2100: 125). Furthermore, these elements have distributed and shifting senses of agency which are themselves encountered and rendered political by human ordering, in both legal and governance terms. In short, the seabed is a vibrant place, one which is always in the making, and where earth’s hydrosphere, lithosphere and biosphere are in dynamic interaction with each other at different speeds and it is these dimensions which mediate any human interventions of deep sea mining.

Thus, in spite of (perhaps because of) its relevance to the Anthropocene, it is difficult for DSM to simply be parsed as *only* subterranean geopolitics in a geographically restrictive sense. The geologic component of this geopolitics is undoubtedly important and can be thought about in a number of ways. These range from the starting premise that the materiality of ‘natural resources’ matters politically (Bakker and Bridge 2006) to more provocative extensions of that idea. Such positions have asserted how specific geological materials and processes can ‘spark’ a new public into being and incite new geopolitical formations (Braun and Whatmore 2010; Marres and Lezaun 2011; Barry 2013). Going further, Elizabeth Grosz concept of ‘geopower’ - what she terms ‘the relations between the earth and its life forms’ (Grosz 2012: 975) - argues that the geologic actually underpins the political where matter-energy is the very condition of possibility for geopolitics. This sort of geopolitics lies at the conceptual and material ‘interface between what *is* and what *is not* negotiable’ (Clark 2013: 49, emphasis in original). Human attempts to speed-up or to slow down the ‘time’ for DSM - through regulation, investment, conservation and so on – engage (sometimes unwittingly) with the deep-geological time of the seabed and are all a key part of the politics that might emerge.

Yet, for all the importance of the geologic, DSM isn’t only located *at* the seabed. The extractive process takes place in, moves through and works with, (sea) water. For example, disaggregated ore on the seabed is gathered by a robotic ‘collecting machine’ which pushes it vertically upwards in a ‘riser pipe’ as seawater slurry to a ‘production support vessel’ (PSV). Once on the PSV, the slurry is dewatered, its solid material transported away to land via another boat, whilst filtered seawater is pumped back downwards to the seafloor, ‘providing hydraulic power to operate the riser’s pump’ (Nautilus 2017a). And so it is that water provides both the medium through which ore is lifted and the source of the power through which the system operates. At the same time seawater, as discussed earlier, is foundational to the continuous formation of the environment’s mineral abundance in the first place. All of this invites an engagement with the geopolitics of water (and watery states) in the Anthropocene, a subject matter that is increasingly being developed in critical geography (Clarke-Sather et al. 2017; Steinberg and Peters 2015).

These perspectives assert that water’s importance to understanding geopolitics is a function of its significance for life and functioning of ecosystems, its ‘unique materiality - heavy, fluid and yet fixed in place’ and its ability to shift between different physical states – solid, liquid and gas (Clarke-Sather et al 2017: 2). The human activity of DSM will both profoundly influence and be influenced by water in these differing states of matter as it operates in the shifting and extreme environments of the deep ocean. Political geography has seized on the question of water's place in the anthropocene to highlight the more specific geopolitics of seas and oceans. This work highlights the voluminous and dynamic properties of the marine that, conceptualised together, can reshape a geopolitics that is 'all too often restricted by terrestrial limits' (Steinberg and Peters 2015: 247). Its theoretical demand for 'thinking from the ocean as a means towards unearthing a material perspective that acknowledges the volumes within which territory is practised' (Steinberg and Peters 2015: 261) is welcome and one that is not only empirically illustrated though this paper's attention to DSM but also extended through its focus on time as a key dimension of the geopolitical. This renewed attention on the sea has emphasised its vibrancy as a space that is more than a static means of connection between places (Steinberg 2013) and is, instead, a geophysical *actor* with political agency (Lehman 2013). Put into conversation with notions of ocean governance and maritime security, this thinking demands that the sea seen as 'placeful' rather than a lawless, 'placeless void' (Germond and Germond-Duret 2016). This is ever more the case, the deeper one goes.

Taking the temporal and spatial vibrancy of the sea as constitutive serves to complicate the ways in which politico-legal control is manifested, most notably through mapping. The sea does not adhere to straight, man-made lines on maps which 'bear little relation to…the seabed' but instead confounds cartographic boundaries with its 'essential fluidity' (Bear and Eden 2008: 488). Indeed, the effectiveness of political technologies used to calculate and categorise deep sea mineral occurrences are likely to be further compromised given the added dimension of depth. As Lindsay Bremner has shown, with reference to the search for Malaysian Airways Flight MH370 in the depths of the Indian Ocean, the ocean's 'fluid ontologies' shape geopolitics and pose 'intractable difficulties for human interactions with it' (Bremner 2015). The ocean's flow and flux is here presented as a political barrier to information and visibility – aspects that will also be key to understanding the geopolitics of DSM.

In addition to its material qualities and dynamics, the sea is also socially constructed in a number of ways, its human perceptions shaped over centuries through their relationships with pre-modern, modern, and capitalist societies (Steinberg 2001). The concern with the discursive construction of the ocean has been taken up by several authors in recent times who have framed the ocean in a range of different narratives and have emphasised that its history is always bound up with questions of the political, cultural and social (Rozwadowski 2005). Steinberg's seminal work on the *Social Construction of the Ocean* centres his analysis around oceanic discourses of development, geopolitics and law (*ibid.*), whilst the more contemporary volume by John Hannigan adopts an approach that views the ocean as a commons either 'harvested', 'shared', 'claimed' or 'protected' (Hannigan 2016). With more specific reference to the seabed, Helmreich narrates a history that has vacillated between the pre-Darwinian view of the seabed as a static and barren space, through the late 19th century vision of a seafloor covered in a 'primordial ooze', to the more modern understanding of a zone full of an 'alien' cornucopia of microbial life (Helmreich 2009: 73-76).

This focus on the ocean as a material and discursive geopolitical actor implies the need to think through its spatial and temporal dimensions; the sea is not a flat surface, but rather a deep, striated and volumetric space which has particular implications for the modes of power and forms of political control that might emerge. This resonates clearly with Stuart Elden's widely discussed thesis that geopolitics and its territorial impulses should be thought about with a vertical dimension in mind

(Elden 2013). 'Volume' is, of course, key to the spatial aesthetic of the ocean but so too does it have important implications for thinking about the ways in which resource extraction and the 'subterranean' is 'secured' politically, a point made in response to Elden's argument (Bridge 2013). Furthermore, this subterranean realm of metals and minerals can be thought about as populated by resources written as agents of time, with the potential to 'become' through processes of human interaction and commodification. The connection of the underground realm to the surficial plane, along with 'its sense of vertical rupture and displacement' is one of the defining aspects of resource extraction in the Anthropocene (Bridge 2013: 56). Moreover, these conceptual connections between the underground and the surface are often manifested physically with actually occurring infrastructures of pumps, pipes and cables. This is what Bridge calls resource extraction's 'umbilical character' where 'social life can only be sustained underground via supply routes from and to the surface' (Bridge 2013: 55). Whilst this seems to be exemplified by the riser pipes of DSM, it is complicated by the fact that many of the spatial configurations of DSM's supply chain are not vertical at all. The actual extraction of ore from the seabed is not vertical and penetrative as might be expected in terrestrial mining but rather is a continuously horizontal cutting process of disaggregation. Similarly, processing the ore will only partially take place *above* the site of extraction; the majority of it is shipped horizontally across the ocean's surface to be processed at landed centres in different jurisdictions[8]. None of which is to mention that the riser pipe moves in relation to the water column through which it passes nor that the whole process is mediated by the rhythms of geology. In short, the geopolitics of DSM is not marked by verticality so much as the three dimensions of volume and the fourth dimension of time.

DSM at the threshold: politics and the spatio-temporalities of seabed resources

DSM stands at both spatial and temporal thresholds. Quite apart from working at the edges of current technological capabilities at a watery depth greater than ever before, it is an industry that has not yet fully formed and is anticipatory in tone. Only one company, Nautilus Minerals (a small corporation in mining terms), has been contracted to begin the actual work of extraction and that has yet to begin partly on account of its ongoing difficulties in raising the requisite finance from investors[9]. Beyond the Solwara 1 project in PNG which is focused on SMS deposits, a series of explorations are taking place globally that target all types of deposit outlined in an earlier section. What this vast range of DSM activity has is common is an engagement with both a politics of space *and* a politics of time (Le Meur et al. 2016; Kirsch 2014). Yet different temporalities are evident. These range from the time of monitoring, generating and transmitting data on seabed resources to the time of their geologic formation, or from the opening of a debate on DSM's impacts before extraction begins to the time, as yet unknowable, when its environmental impacts are realised. In this section, I detail examples that highlight some of these spatio-temporal dimensions in order to show the ways in which they are crucial to understanding the emergent geopolitics of DSM.

[8] For example, the ore extracted from the Solwara 1 deposit in Papua New Guinea will be processed in China.
[9] Despite limited shareholder backing from larger corporations, Nautilus Minerals has repeatedly signalled the need for finance in order for the Solwara 1 project in PNG to continue its operation (Mining Journal 2018). Against this background, both its chairman, Russell Debney and its vice president of PNG operations, Adam Wright, have resigned in early 2018.

Much of the human activity surrounding DSM aims, from different perspectives, to anticipate its effects and potential. One obvious example concerns the attempts made by contractors to fix mineral incidence in space and time through resource 'inference', a process which aims to establish metal and mineral abundance and quality yet can only do so with a low level of geologic certainty. One of the key aspects of the economic case that has enabled DSM in Papua New Guinea is the relatively high grades of copper and gold found on the seafloor. As Nautilus Minerals' environmental impact assessment report highlights, 'the viability of the project is underpinned by the high grades of Solwara 1 [where] inferred resources are 1,300,000 t of 7.5% copper' (Nautilus 2008: 12). Despite only being 'inferred' (and thus based on seismic and geologic data and not on a drillhole campaign), the deposit compares favourably with 'land-based copper mined, where the copper grade today averages 0.6%' (Nautilus 2017b). Inferring a mineral deposit's commercial viability in the deep sea depends on a huge range of technologies that aim to make mineral deposits visible and legible to investors. Owing to the unique challenges and complexities of 'finding' deep sea resources, a combination of GIS, bathymetry, water chemistry, drill sampling, geophysics and electromagnetics is used to identify potential sites of extraction. Each of these engages with different materialities (of water, of plumes, of the seabed etc.) yet they all rest on the core concern to make resources 'be'. Of course, such forms of representation can only ever partially satisfy the demands of investors and financiers: as Nautilus's CEO has been quoted, 'we can show them [investors] models and consultant reports, but there's nothing like actually doing it' (Nave 2016).

It is a reminder that although proponents of DSM stress the short time frame for extraction relative to terrestrial mining – a key argument made in favour of the industry – the actual length of mining projects as a whole is much longer. This includes sometimes decades-long processes of pre-operational work such as that just described but also the post-operational work after extraction has taken place (Le Meur et al. 2016). Extraction might take place in a relative moment at the deep-sea bed, but the longer-term impacts on earth systems, the dispersal of sediment plumes into the ocean's water, and the effects on understudied ecosystems are likely to significantly amplify current resistance to DSM from campaigners and be the key to a politics of contention in the future. Indeed, acting as a sort of prelude, tailings from the extractive industries are already being disposed of in the deep-sea through 'deep sea tailings placement' (DSTP)[10] but little is known of their effects. Indeed, tailings may be 'placed' in the deep-sea but they disperse rather than remain sedentary once deposited. That DSTP only emerged as a consequence of the political volatility of terrestrial tailings management suggests that in time it may not be the seabed but elsewhere where the politics of DSM emerges.

As introduced earlier, new legal mechanisms are also attempting to articulate and anticipate the key areas of contention raised by the deep-sea's unique materiality. Mineral 'resources' are seen by UNCLOS as being '*in situ*' and thus, are fixed literally 'in position' yet at the deep-seabed, they dynamically shift between different states of matter in the very process of their formation. This spatio-temporality is also exemplified by the deep-sea bed's volcanic abundance (around 75% of the earth's magma output originates at mid-ocean ridges (Speight and Henderson 2013) and volatility which creates new biogeographical and topological formations. Yet an erupting underwater volcano doesn't so much 'obliterate life' as 'hit the reset button' when the deep sea is conceptualised as a

[10] DSTP is being trialled in several contexts globally including in PNG where four terrestrial mine sites have implemented this system.

place of ‘death and rebirth’ (Qiu 2010: 284). Life (both microbial and human) disperses and adapts to such extreme events. This will be a key part of the politics of DSM in PNG where the active North Su volcano is in the immediate area of imminent resource extraction. From a pro-DSM perspective, such ‘natural’ ecological and geologic resilience can justify the act of mining given that the magnitude of disruption wrought by a volcano is likely much larger than that caused by DSM machinery. The act of making these uncertainties legally ‘certain’ must address a nature that is in constant motion and is never quite stable either in time or in space.

A final example of this anticipatory politics relates to the development of DSM specific technology which takes different forms. DSM activity might adapt to the violence of active volcanism by locating, monitoring and even avoiding it; commercial SMS extraction tends to operate at inactive (rather than volcanically active) hydrothermal vent sites. Remote operated vehicles (ROVs) explore or potentially extract from the depths under high levels of pressure where data moves between machines on the sea floor and computers on the water’s surface. In this way, the ocean gets reworked as a ‘technological zone’ where ‘technology is expected to forge connections across and establish boundaries around…a firm or a nation-state’ (Barry 2011: 25). Nautilus Minerals, for example, separates its mining equipment from the human realm almost entirely by emphasising the spatial remoteness of the seabed from human presence. As its corporate social responsibility report states, ‘socio-economic and socio-cultural issues that are normally associated with terrestrial mining projects are absent from the Solwara 1 Project as he majority of Project activities will occur at sea and not be located on occupied land’ (Nautilus 2008: 42). In doing so, the company reasserts the Enlightenment ideal of separating nature and culture where the seabed is representative of a wilderness ‘out there’, and the water column is seen as an inert zone of separation from the human which is somewhere landed and elsewhere, unaffected by DSM. However, it is more appropriate to think of these as sites where nature and culture, the human, nonhuman and technology, are part of an assemblage. Thus, ROVs become examples of the ocean’s ‘submarine cyborgs’, where scientists (people) ‘are merging with [their] data’ through the control of remote equipment (Helmreich 2009: 228). And even though extraction takes place on the seabed, only some of the processing takes place at sea; the majority of waste treatment takes place on land just as it would with terrestrial mining. In other words, contrary to Nautilus’s assertion, DSM’s politics is always about the human just as it is also about the material and the nonhuman.

The politics of DSM technology is then, following Elden, understood here to encompass different ‘techniques for measuring land and controlling terrain’ (Elden 2013: 36). This means that it is not just the physical machinery of extraction and exploration (boats, submarines, cutting equipment, pumps, pipes and cables) which is relevant, but also that it includes the political technologies of ‘calculation, visualization and manipulation around volume’ (Bridge 2013: 56). More than just being concerned with the territorialisation of space, they are bound up in a politics of time. That is the case whether they try to calculate deep-sea ore abundance or measure and map environmental risk and ecological impact so important to managing critiques of all extractive practices. Conceptualised in this way, the political technologies of DSM, are also at the threshold physically and linguistically: new machinery is required to counter (and sometimes mimic) the ‘natural’ world and new language and media is required to write it, map it, to make it knowable to capital – to literally geo-graph it. DSM’s technologies are ultimately about bringing a putatively unknown and unseen deep-sea into being as a political object.

As we have seen, the deployment of specific machines to do the work of DSM in the deep, far from being absolved from the human touch, actually connect the technological to an assemblage of human and nonhuman parts. Data is gathered and facilitated by 'equipment' such as submersible 'ploughs', 'trenchers' and computers that rely on the material realm 'in order to assert their existence' (Marres in Altena et al. 2015: 240). It is a telling coincidence, that the prime quality grades of deep-sea metals and minerals being mined get commodified as crucial components of the very machines and technologies used to locate and extract them in the first place. Put more simply, DSM technology, for all its engagement with water, is 'subsidised' by the earth. On the one hand, DSM's technology opens up new kinds of exchange and cultural interactions with both the geologic and the ecologic, part of a 'technoscape' that 'moves across various kinds of previously impervious boundaries' (Appadurai 1990: 297). Yet it is also part of an 'industrial time' complex that is interdependent with 'nature time', perhaps part of a 'timescape' which 'conceives of the conflictual interpenetration of industrial and natural temporalities as an interactive and mutually constituting whole' where 'each in/action counts and is non-retractable' (Adam 1998: 56). To scrape away at the seabed is to disrupt the layering of geologic time which is in formation at different speeds depending on the type of deposit. To pump mineral rich ore a mile vertically in a matter of minutes is to compress that time dramatically. To manage the environmental impacts of a sediment plume or a burst riser pipe is to contend with the interpenetration of industrial and geologic time. These temporalities combine with the deep sea's material qualities of extreme pressure and depth, geologic volatility and relative invisibility to present a unique challenge for governance.

The governance of DSM rarely, speaks to the same temporal register as the geologic. This is nowhere more clearly the case than in national framings of 'economic development'. It is perhaps no surprise that in Papua New Guinea, it is SMS deposits that have emerged as the first type of DSM to be commercially trialled. The fast speed of their geological formation is such that it aligns well with the short-termism so familiar to electoral cycles around the world. To be able to demonstrate that DSM is viable represents valuable political currency to the developmental state especially as any negative environmental effects are not likely to be demonstrated in anything like the same timeframe.

One example of DSM's political relevance in the present is its scripting as part of the 'blue economy'. This neologism served to place the ocean as central to a market-driven approach to environmental governance and development. Since then, the concept has been extended to think beyond the marine economic sectors of fishing, aquaculture, marine-based tourism, shipping and transport and offshore wind power and to include DSM within its remit. This is significant because it shifts the reach of the economy (its spatial fix) *deeper* than the other examples to a lightless surface (the seabed) below a surface (of water). In doing so, it again opens up the necessity of thinking about political governance in terms of a volume where its materiality is one in 'which humans are ill-equipped to function' (Lehman 2013: 52). Given that depth has been used to obscure all manner of political histories and geographies, from the wilful drowning of slaves in the name of financial gain (Baucom 2005) to the military secrets of cold war submarine research (Broad 1998), it should not be marginalised in the emerging political geography of DSM either.

Writing DSM into the language of sustainable development is particularly challenging because of the high levels of uncertainty that surround efforts to calculate and inventory the seabed and its associated ecology. However, its unique characteristics can also enable political opportunities for the rentier state, a notion not lost on Papua New Guinea's government. Describing itself as a 'mining state', PNG's Mineral Resource Authority explicitly states that its 'wealth…is a result of its geology; based on anomalies from past and current exploration efforts, it can offer to explorers the opportunity to multi element discoveries [sic], including gold, copper, rare earth elements, nickel, cobalt, chromium, molybdenum, iron and platinum' (MRA 2017). Politicizing its mineralogy in this way, the state thus creates imagined geographies of hope, economic possibility and transformation. It is the deep-sea's materiality, temporalities, obscurity and possibility that combine to create a 'development narrative' (Burchardt and Dietz 2014: 471) so central to the emergence of an 'extractive imaginary' (Childs and Hearn 2017: 847) and which will help to shape social world-views on DSM in the future.

Conclusion

The geopolitics of DSM can be located at a spatio-temporal threshold. Its minerals and metals are constantly being 'made' into resources through a combination of social, nonhuman and geologic forces. DSM has emerged, for example, as a 'necessary' response to the demands of capitalist society whilst at the same time being constantly shaped by the interaction of earth processes and nonhuman life. In other words, understanding of the future geopolitics of DSM must be attentive to the 'geo-', and the 'possibilities that matter affords to us' (Richardson and Weszkalnys 2014: 15) whilst remaining always cognisant of the historic and contemporary socio-economic orderings that govern its practices. It is easy to conclude that viewing the 'becoming' of DSM resources as political - with all their complex assemblages, their shifting elements and states of matter - is somehow misrecognised by the capitalist impulses to secure and market them. This assumption is manifested in at least two ways. Firstly, proponents of DSM speak of it as a response to resource 'scarcity', framing the deep-sea bed as generative of future possibilities that are somehow vital to sustainability. In this sense, current and future scarcity is what drives and defines DSM's emergence and, more broadly, the 'relentless future of a generalized resource-based economy' (Ferry and Limbert 2008:7). Secondly, the corporate reworking of the deep-sea as a 'natural resource' inheres the idea that it is an inert, passive and inorganic target for extraction. As we have seen, the SMS sites identified for extraction are typically focused on inactive (rather than active) hydrothermal vent systems.

Yet, it is a mistake to dismiss the political technologies used in DSM as ignorant of the sea's essential fluidity or the seabed's dynamic qualities. The deep sea's liveliness and its material properties may actually be very well recognised by those very actors who seek to exploit it. 'Calculating' and 'exploring' the deep-sea does not only territorialise and 'secure' space but it also divides up an otherwise flowing and continuous material existence in a deliberative sense. Mapping the sea-bed is based on a calculated set of de-cisions and in-cisions (a series of 'cuts') that are made to simultaneously render it profitable (to industry) or knowable (to science) whilst being mindful of its material dynamism. The deep-sea miners of contemporary political formations might, in fact, be amongst the most attuned to the vibrant materiality and temporalities of the oceans in which they work, actively thinking about the geologic violence and agency of volcanism, shifting states of mineral matter and the challenges of darkness and pressure that they face. The geopolitics of corporate social responsibility strategies, practices of mapping and communicating the science of DSM are all likely to be shaped by an understanding, not an ignorance, of its nature. There is precedent for this: it was (terrestrial) miners who, in the 18th century, first conceptualized the earth in terms of volume, rather than area. As Rudwick shows, mining was the industry which not only enabled 'empirical data on the dimension of depth in the earth's crust, but also – far more importantly – a distinctive way of thinking and even seeing. Anyone involved in the mining industry…worked in a three-dimensional world of rock-*structures*' (2005: 84).

In order to 'see' DSM's geopolitics emerge, an engagement is needed with the 'natural' processes of becoming minerals which are found in qualitatively unique, differing and extreme environments of the deep-sea. In the deep-sea, where magma meets water, solid meets liquid, where levels of pressure and sound dramatically vary, a geopolitics is needed that is framed by the (geo)power of earth processes (Grosz et. al 2017). This means placing attention on the political possibilities enabled not only by human-environment relations, but also by the relationships between objects that are beyond the human - a 'material politics' (Barry 2013) where deep sea minerals can't be isolated from their origins, the things that they do and the impacts that they have. Applied to DSM, each stage of mineral and metal exploration, extraction, transportation and processing can be read as a moment of congruence between the nonhuman with the human; be it through political and social construction and regulation or built resource infrastructures. Despite their dynamic, vibrant and unruly 'political metabolisms', human action attempts to 'stabilize' deep sea matter (Richardson and Weskalnys 2014) as particular moments in space-time - as particular commodities, legal artefacts and technological challenges to be overcome. Deep-sea environments are simultaneously complex, diverse and relational and thus demand 'a better encompassing interpretive frame' for studying its (geo-)politics, one which is seen as emergent and which operate at the threshold (Dalby 2015: 47).

And so it is that the (geo-)politics of DSM is situated at a particular four dimensional moment where the resources identified for extraction are characterised by their changing form, spatialities and temporalities (Ferry and Limbert 2008). These, in turn, might ultimately be about how the subterranean world comes to be *represented* and made known within a broader geographical matrix of sites and spaces. If the Anthropocene is about the recognition that 'human activities now intervenes substantially in the circulation systems' of air and water which drive the 'exceptional mobility of the earth's crust' (Clark 2016: 3), then how might DSM be described? This question is no longer just a matter of speculation but rather is provoked by actually occurring extractive activity such as recent developments in Japan where, at the time of writing, zinc, gold and copper are being mined 1600m below the surface of the sea (Japan Times 2018). The way that its politics is designed and imagined will have to engage with the 'subterranean' in both meanings of the word. How is DSM's politics to be considered in terms of its predominant definition; of happening 'beneath the earth's surface'? As we have seen, this is horizontal extraction taking place at the surface of a surface beneath a surface. Secondly, 'subterranean' infers the idea of being 'secret' or 'concealed'. How the deep-sea's 'hidden' nature is confronted will profoundly shape its politics. As leading oceanographer Cindy Lee Van Dover states: 'there is no real boundary to the part of the planet I think of as the deep sea…In my mind, the deep sea encompasses the depths of the open ocean beyond where daylight penetrates – beyond where the sun at noon becomes twilight, beyond darkness, into utter black' (1997). What 'subterranean' geopolitics might emerge from that darkening abyss?

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