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The pore space scramble; challenges and opportunities for subsurface governance

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ABSTRACT

There is a rich literature on environmental governance that provides critiques and conceptual tools on how various environmental 'arenas' or overlapping global systems should be governed e.g. climate, energy, oceans (Cherp et al., 2011; Berkes, 2006; Underdal, 2010). In this paper we argue that the geological subsurface should be considered as a new arena for governance in its own right. The arguments for this are presented by considering current and future challenges the subsurface will face as its utilisation evolves and intensifies, particularly in the context of both energy security and low carbon energy. Three main challenges are highlighted; ownership, access and long term stewardship. These challenges are presented using the illustrative context of subsurface pore space for the long term storage of CO_2 from Carbon Capture (CCS). This is presented in the UK context but ultimately has implication for global subsurface governance going forward.

1. Introduction

The subsurface has a long history of industrial resource extraction and humans have been utilising the subsurface since pre-historic times. In the modern era it has been used for mining coal, metals, salt and limestone, building materials, groundwater extraction and drilling for oil and gas. This extraction requires access to underground spaces of different kinds, used over different timescales and by different actors (Lynch, 2004; Nef, 1967). It relates to different structures (and uses) such as caverns and tunnels (suitable for human access), bore holes (to gain access to reservoirs of underground water, oil and gas fields) and pore spaces (microscopic spaces in the rock that contain liquid i.e. oil or saline water, or gas).

Demand for resources such as those utilised through the subsurface (e.g. oil and gas) continue to increase. Alternative methods in which to source energy producing fuel from the underground are developing rapidly and the ways in which energy systems exploit the underground are evolving and intensifying (Small et al., 2014). The most notable in terms of current controversy is hydraulic fracturing for shale gas, receiving media attention (e.g., in the UK and USA) over public concerns related to safety and environmental health risks (Boudet et al., 2014). However, the subsurface also holds much value (both economically and practically) in its *storage* ability. For example, short-term (e.g. Compressed air energy storage or seasonal natural gas storage) and long-term storage of natural gas or long term storage of wastes such as CO_2 resulting from carbon capture and radioactive material (Evans et al., 2009). It is in this instance where the physicality of the subsurface and the *pore space* in particular becomes important. It is these distinctive volumetric properties that shift the subsurface from a one way site of extraction to a two-way use of extraction and storage. This then reopens the subsurface as a site of new opportunity and as a site for contestation. It causes a reassessment and advancement of geological knowledge (assessment of opportunities and risk), of the role of property regimes and access, and of the implications and challenges of using the subsurface in ways which will alter the properties of the subsurface on both human and geological timescales.

To illustrate the dynamic nature of the subsurface in terms of its geological properties and the role and interchange between the geo and social, one particular proposed use of the subsurface (in the UK context) will be used throughout the paper. This will focus on the use of subsurface pore space for the storage of CO_2 as a result of carbon capture and storage (CCS). Carbon dioxide capture and storage (CCS) is a technical concept for the separation of CO_2 from industrial processes or their flue gasses in combination with long-term sequestration of the substance, typically in the pore space of geological formations. CCS technology is ideally designed for large point source emitters of CO_2 such as power plants and particular types of heavy industry. CCS therefore, has been presented as a solution for the decarbonisation of

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these industry sectors (IPCC, 2005, 2014).

This paper has two main aims; firstly it explores emerging theoretical frameworks addressing the distinct and multiple volumetric properties of the subsurface and the role of verticality, that challenge our current conceptualisation and commodification of the subsurface and its use (Elden et al., 2014; Bridge, 2013; Braun, 2000). It also extends this thinking of geological spaces to consider the role of the 'geosocial', or in other words to consider how geological forces and it's individual properties have shaped and are continuing to shape us as a society (Clark and Yusoff, 2017; Clark, 2017).

Secondly, the paper draws on concepts from the environmental governance literature (e.g. Berkes, 2006; Cherp et al., 2011; Ostrom et al., 1994; Underdal, 2010) and the earth governance literature (e.g. Biermann, 2007) and reflects on the use of these concepts for exploring the subsurface, given its interplay between environmental, earth and social systems. In this sense, it is this interplay between these arenas, or where the *geo* meets the *social* (geo-social) that makes the subsurface so important, and where this paper aims to make it's contribution. It extends the current framing of governance literatures and brings them into conversation with the role of verticality and geosociality, through the case study example of pore space for carbon capture and storage (CCS). The paper ultimately argues that our existing concepts of environmental and earth governance are not currently 'fit for purpose' given that they do not capture the unique and shifting potentiality that the subsurface provides.

The following Section 2 will briefly introduce the concept of the 'geosocial' before discussing the role of verticality, volume and the mapping of strata. In Section 3, the emerging role of pore space for CO_2 storage will be introduced (using the UK context and regulatory frameworks as an example) and this will then be followed by introducing the governance literature in Section 4. The final Section 5 will bring these conceptual and theoretical debates together, and extend thought on what this might mean for subsurface governance into the future.

2. Where the *geo* meets the *social:* geo-social

The notion of the geo-social is beginning to emerge in the social sciences as a way of understanding the emergence of the Anthropocene (Clark, 2017; Clark and Yusoff, 2017; Yusoff, 2017). However, instead of positioning thought as to how we 'socialised' geology, the perspective is altered to consider how geology has shaped society over time, or as Yusoff (2017, p. 106) puts it, 'an expression of social forms as a product of geologic forces'. While acknowledging the concept of the Anthropocene and recognising the way in which social processes have impacted and shaped earth processes in varying ways, the geosocial also recognises the way in which earth processes also shape aspects of social life. Examples of this geosocial relation will emerge, and be explained in more depth throughout the paper however the following will specifically explore this with relation to subsurface spaces and the role of the vertical.

2.1. Subsurface spaces and the role of verticality

From early modernity an intensification of engagement and transactions with the subsurface began to emerge and opportunities for exploiting subsurface resources were uncovered, for instance the 15th Century European mining boom and early industrialisation in late 18th Century. The distinction between the horizontal plane and what lies below was first made apparent through the role of property regimes and the role of the split estate, where the property rights of the surface became detached from the fuels and mineral below (Braun, 2000; Bridge, 2013). This distinction emerged to ensure access and subsequent commodification could be utilised to the max. Braun (2000), using a particular example of this in the early 19th Century Canadian context, explains that in order to optimise it's *vertical* territory, property regimes needed to 'better reflect the internal architecture of the earth' thus enabling individuals to better exploit the nation's geological resources (p. 34). In a similar vein of the geosocial's proposition, that the geology has played a part in shaping the social, Braun (2000) argues that earth science (and the changing knowledge of the earth scientist) plays a key role in developing 'political rationality' in 19th Century Canada.

Verticality and territory have been discussed in more contemporary settings also. For instance, Elden (2013) calls us to consider how the way we think about volume changes the way we think about the politics of space. The discussion in particular explores the role of territory, not just in terms of property, Sovereignty or ownership, but also through the 'exchange, use value, distribution and partition' of (volumetric) space (p.35). Moreover, it is suggested that territory is a continuous process made up the remaking of many assemblages, and not a static outcome of events.

Bridge (2013) builds on the propositions of Elden's verticality, encouraging a move beyond thinking of industrial capitalism as purely a product of horizontal or surface politics (for instance Bridge p.56, uses the example of the division of town and country). Vertical rupture and displacement, Bridge (2013) suggests, are key to conceptualising the link between subsurface and surface processes, highlighting the re-accumulation of carbon in the atmosphere, that has been vertically displaced from it's store in the rocks below (Bridge, 2013). The practices of power that enable access and exploitation of such resources are reliant on a range of geo-metrics and geological knowledge that inform estimates of voluminous structures and extents (i.e. subsurface properties), allowing for volume to turn to *value*, and the subsequent political rationalities that ensue (Bridge, 2013).

It is in this sense where the subsurface's unique volume and physical structure, such as pore spaces (voids), fractures, fissures and veins, become the key component in understanding, and perhaps directing the surface and spatial political discourse, where the geo not only meets, but shapes the social. And, far from being a relic of past activity, the subsurface and its properties are opening up new ways for us to imagine and engage with it's use, and in turn leading to a new rationalisation of the governance and political-legal frameworks that are used to structure ownership, order, control, value and access. In the example presented in this paper, this is shown through the voluminous ability of its pore space (or voids) as a new storage opportunity. This example also highlights and extends the concept of carbon displacement into the atmosphere, into a more immediate cyclical process of carbon displacement, capture and then storage in the pore spaces below.

2.2. The mapping of strata

Elden (2013) and Bridge (2013), call for us to consider the ways in which verticality in the subsurface becomes bounded, play different roles and subject to different governance structures. For instance, this can be illustrated through the way the subsurface strata is mapped into bounded spaces.

From a practical utilisation or commodification perspective, the subsurface is categorised into specific geological spaces and mapped as individual parcels of strata. Each individual parcel or strata will be of interest to different stakeholders depending on the geological properties of that particular space. Over time, the diversity in use of subsurface properties has increased and so, the 'planning' of strata on both short and long-term timescales has become more complex. For instance, there may be other forms of subsurface use where interactions with adjacent substrata parcels are not viable, for example the deep geological burial of radioactive waste. Not only does it need to be geologically defined in term of its suitability to house this waste, thought also needs to be given to the surrounding parcels of substrata to ensure they would not be utilised now or into the future. These scales are also difficult for us as citizens and policymakers to fully comprehend, and go far beyond our imagination of the future, into geological timescales. On a practical level this void of comprehension results in a significant