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"Do you Know What's Underneath your Feet?": Underground Landscapes & Place-Based Risk Perceptions of Proposed Shale Gas Sites in Rural British Communities☆

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Abstract Resource extraction relies on human interaction with the underground, often near rural communities. Yet, little research has explored localized, place-based relationships to the underground and subsequent concerns tied to proposed energy activities. This paper highlights the importance of place in localized risk perceptions of proposed shale exploration in two rural communities in the United Kingdom. Through qualitative case studies we examine how senses of place and place-based knowledges are shaped by underground landscapes. Further, we explore how these inform local risk perceptions of shale gas exploration. Our findings demonstrate how senses of place and place-based knowledges in each community are embedded in local rural culture that stretches back multiple generations, and are at least in part rooted in human connections to, and understanding of, the subsurface. Connections between surface and underground aspects of places create concerns about distinctiveness, which heighten residents' perceptions of more generalized shale gas risks. The research findings broaden our understanding of how places encompass both surface and underground landscapes, with significant implications for risk perceptions in energy contexts. These findings raise important questions for incorporating place-based and plural sets of

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knowledge in risk management and decision-making for future underground energy projects that contribute to net-zero strategies.

Introduction

About 80 percent of energy used to meet global demand is generated through the extraction of fossil fuels from the subsurface (Ritche, Roser, and Rosado 2022), a practice typical across rural landscapes. As efforts grow to decarbonize energy systems and achieve net-zero, proposed solutions such as geothermal energy and storage, as well as carbon capture and storage also depend on underground interventions for implementation, (Stephenson et al. 2022) and are crucial for supporting uninterrupted energy supplies (van Gessel et al. 2021). Essentially, underground interventions have been

Figure 1. Map of Great Altcar.

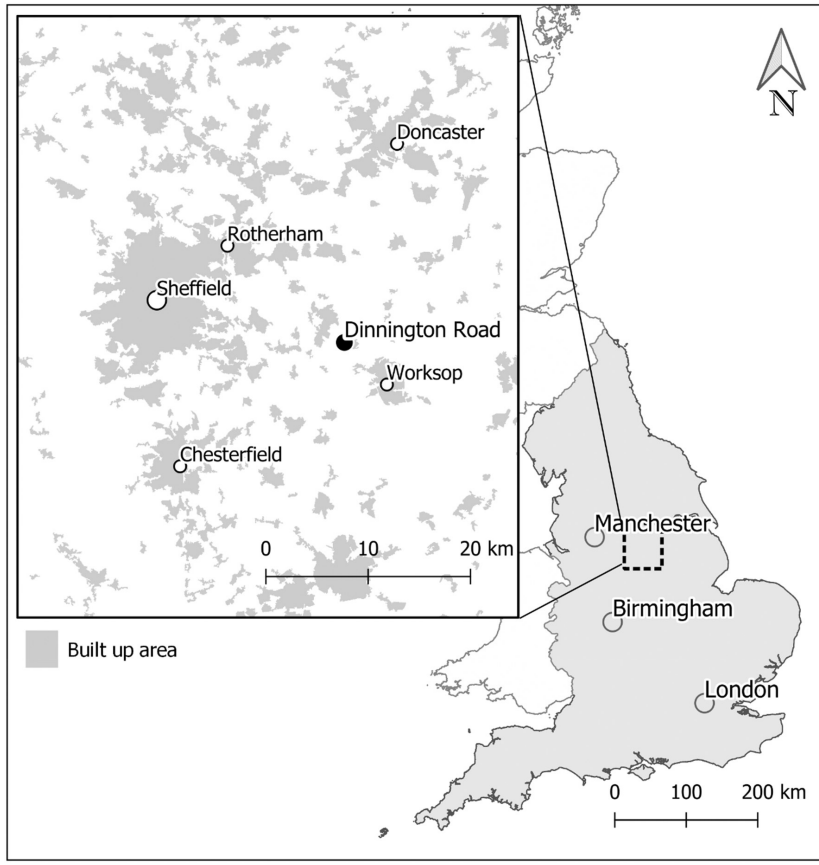

Figure 2. Map of Woodsetts, UK.

and will continue to be necessary for energy production and storage moving forward. As such, rural people and places have played a crucial role in our energy past, and will likely play a crucial role in our collective energy future.

Precisely what options are pursued to reduce carbon emissions and meet global demand depends in part on public perceptions about different energy sources and practices where new projects are proposed (Viklund 2004). Risk perceptions can influence public support or opposition to different types of energy projects (Tan et al. 2022) which can, in turn, influence whether a proposed energy project moves forward (Heagle, Naterer, and Pope 2011; Mulvihill, Winfield, and Etcheverry 2013; Shaw et al. 2015; Simard 2018). While traditionally public concerns about energy-related risks have been focused on

aboveground processes, more recently an emphasis on subsurface risks (e.g. earth tremors) has challenged how researchers, policymakers and operators communicate the uncertainties and unknowns of the underground (Gibson et al. 2016; Stewart and Lewsi 2017; Volchko et al. 2020).

Previous research demonstrates the important role of place in shaping public concerns, risk perceptions, and support of proposed energy projects (Batel 2020; Devine-Wright 2009; Vorkinn and Riese 2001; Wester-Herber 2004). While in the past localized resistance to energy projects has been attributed to "NIMBYism," more recent research demonstrates how resistance is more nuanced, rooted in sense of place and place attachment (Devine-Wright 2009). In the context of energy development, a plethora of place research has been undertaken on relationships between people, communities, aboveground landscapes and surface-level concerns (i.e., visual impacts, see Wolsink 1988, 2000), particular in and around rural communities. For example, in the United States (US), Jacquet and Stedman (2013, 2014) and Junod et al. (2018) find links between perceived threats to place and opposition to shale development. As new literature emerges on the relationship between place and perceptions of shale gas extraction, how place-informed understandings and connections to rural *underground spaces* might inform risk perceptions of locally proposed energy projects remains underexplored. That is, we know little about rural place particularities and distinctiveness (Devine-Wright 2009, 2011b) tied to the subsurface as a distinct part of a place.

Better understandings of place-informed risk perceptions tied to the underground will be essential for ensuring that low carbon and net zero energy projects (e.g., geothermal, carbon capture, and storage) can move forward and appropriately address public and community concerns. Lessons can be learned from the case of shale development, a practice which often involves injecting a large volume of a highly pressurized mixture of water and proppants into a well to fracture shale and release unconventional natural gas (Norris et al. 2016). Research demonstrates that these practices have led to underground concerns such as water contamination (Kroepsch 2018), induced seismicity (Partridge et al. 2021) and mineral ownership (Ryder and Hall 2017). Given the lack of research around underground and surface-level place connections and how these (1) shape senses of place and place-based knowledge and (2) inform risk perceptions of shale gas exploration, here we ask:

1. How can underground landscapes—as a distinctive part of a place—inform senses of place?
2. Who is seen as possessing trustworthy, place-based knowledge about the local underground that is relevant in the context of proposed shale gas exploration?
3. How do senses of place and place-based experiential knowledge shape risk perceptions of shale exploration?

To address these questions we draw on two qualitative case studies of rural communities in the Midlands and north of England where shale gas exploration was proposed.

Literature Review: Underground Space, Place & Risk Perception in Energy & Shale Gas Contexts

While the "underground" as a spatial concept has been explored by geographers (Elden 2013; Gibson et al. 2016; Stewart and Lewsi 2017; Williams 1990), less is known about underground space as meaningful place, or, how "place" may be constructed from connections to and across the distinctive but connected spaces of the surface and underground. In energy contexts, Partridge et al. (2021) have explored the social construction of depth and risk perceptions tied to shale gas, but fail to demonstrate underground place-based connections. Instead, their focus is on US and United Kingdom (UK) participants' concern about uncertainties around shale gas risks, and how fracking might disturb the Earth and cause instability. A growing body of literature has examined risk perceptions related to fracking, both in terms of the broader public opinion on the practice, and concern expressed by people near proposed or existing shale gas sites (see Tan et al. 2022). Despite many existing public concerns tied to subsurface issues, little research has focused explicitly on the underground as a distinctive part of place that shapes localized concerns with shale interventions. In addition, what constitutes "risk" remains too narrowly focused. For example, while risk communication literature often includes a focus on both human health and the environment, place-based issues are often overlooked (Wester-Herber 2004). As noted by Jacquet and Stedman (2014), place-based risks of shale gas might include social disruption as well as "spoiled" place-based identities rooted in rurality. Further, how risk perceptions of these practices are shaped by place-based knowledge and relations that expand "place" to include underground spaces remains largely unexamined (Bobbette and Donovan 2018).

Place is distinct from the concept of "space," because it is tied up with meaning, emotion and attachment associated with a particular location (Devine-Wright 2009; Williams 2014). Conceptualizations of

place in energy research are diverse, including several distinct but related concepts such as: place attachment, place identity, place-making, sense and senses of place, place disruption and "place at risk" (Devine-Wright 2011a; Jacquet and Stedman 2014). We understand "senses of place" as pluralistic, referring to how people (individually or collectively) perceive, interact with, experience, think about and develop feelings of belonging through their environment, that is, places where they live, work and play (Devine-Wright 2022; Raymond et al. 2021). Senses of place are tied to both human-environment relations and human-human relationships, so meaning can derive from geographic region, location, landscape, social and cultural experiences, rituals, symbolism, ancestral connections, memories, physical or social uniqueness, and how places are known, imagined or contested (Feld and Basso 1996; Kyle and Chick 2007; Shamai and Ilatov 2005; Tuan 1977). Further, senses of place are closely tied to other processes and relations to place, informing place-making and meaning, place-based identity, place attachment, place at risk and place disruption (Groat 1995; Jacquet and Stedman 2014; Junod et al. 2018). In the context of rural studies, sense of place and place attachment research has spanned a variety of socio-environmental relationships, such as conservation (Mook, Goyke, and Dwivedi 2022), land use change (Keske et al. 2017), rural amenities and well-being (Brehm, Eisenhauer, and Krannich 2004), views on climate change (Caretta, Rothrock, and Zegre 2022), environmental concern (Armstrong and Stedman 2018) and perceived risks and impacts of energy development (Jacquet and Stedman 2013; Jacquet and Stedman 2014; Junod et al. 2018).

In early place-energy literature, Vorkinn and Riese (2001) examine the role of place in localized efforts to contest energy through a "Not in My Backyard" framework (Batel 2020; Scott and Powells 2020). Devine-Wright's (2009) challenge of this approach focused instead on how place attachment could lead to place-based protectionism if projects were interpreted as a threat to existing place meanings and identities. Primarily, place-energy research explores resistance to energy projects rooted in fears of threats to place and negative place change in host communities, particularly when industrial activities are proposed in rural areas in the countryside (Antadze and Gujaraidze 2021; Devine-Wright 2022; Ryder and Devine-Wright 2021). Energy infrastructure projects that disrupt places in such a way have the capacity to erode agency and identity of people and their community (Groves 2015), which is unsurprising given the established psychological influences of place on identity (see Wester-Herber 2004).

A small number of studies examine place-based meaning in the context of shale exploration. Sangaramoorthy et al. (2016) find that residents in West Virginia experienced distress tied to place transformation and conflicting meanings of place and social identity. Similarly, Willow et al. (2014) note how Ohio residents see shale gas as a threat to place distinctiveness. Jacquet and Stedman (2014) suggest a link between perceived threats of disruption to place-based identity and active opposition of shale gas. They also note how other actors might strategically frame shale gas to align with place and community identity in an effort to reduce the risk of perceptions of threat to place identity. Junod et al. (2018) build on this work, concluding that a lower perceived risk to place meaning and identity correlates with more positive attitudes toward development. Beyond these works, several studies have examined local impacts and lived experiences of shale gas, engaging on matters of place without using it as a specific theoretical frame (i.e., see (Ladd 2018; Malin, Ryder, and Hall 2018; Mincyte and Bartkiene 2019; Perry 2012; Ryder 2017; Short and Szolucha 2019; Sovacool et al. 2020). Most recently, (Ryder and Devine-Wright 2021) demonstrate how a shale gas operator failed to account for community identity and place attachment while simultaneously dismissing and challenging place-based knowledge.

Yet place framing has primarily focused on aboveground issues—such as visual impacts, the "industrialization of the countryside," and impacts to housing, community, public health, wildlife and the environment (Batel et al. 2015; Devine-Wright and Howes 2010; Jacquet and Stedman 2014; Junod et al. 2018; Kim and Chung 2019; Ryder and Devine-Wright 2021). Thus, how "place" is conceptualized when it expands to include the underground as a distinct aspect of place formation has yet to undergo serious inquiry. Here we aim to fill this research gap through qualitative fieldwork in two UK case study communities where shale exploration has been proposed.

Methodology

Qualitative methods are appropriate for research focused on lived experiences and social constructions (Marshall and Rossman 2016). We developed two in-depth case studies to explore the lived experiences and place-based concerns of residents in Woodsetts and Great Altcar, UK who faced potential shale exploration in their locality (see Figures 1 and 2). The cases were selected because we were interested in studying communities that were still in anticipatory stages of the process where drilling had yet to occur. Additionally, we wanted to select communities that had not yet been studied. Finally, we aimed to examine experiences of proposed shale exploration in different areas of rural England, given

persistent concerns about the impacts of energy infrastructure projects on the UK countryside (see Batel et al. 2015).

Case Study Background: Woodsetts

Woodsetts is a village 17 miles east of Sheffield in South Yorkshire, near Dinnington and Worksop. With a population of around 2,000, Woodsetts consists of one major intersection that can take residents and visitors to the church, the village hall, the school and the pub. Beyond the village are agricultural fields, where Greenbelt land (protected from development) can be traversed via footpaths and bridleways. Regionally the area is home to a variety of protected areas, such as the National Trust site, Clumber Park. From Woodsetts one can walk to Anston Stones Wood, a site of Special Scientific Interest (SSSI) and home to the stone that was originally used for building the UK Parliament. Between the village and Anston are two small patches of ancient woodland. A conversation with any resident will also likely reveal the village residents' ties to the regional coal mining history as the crux of the local workforce. Ineos Shale was granted the license for shale exploration on 15th December, 2015. The community organization, "Woodsetts Against Fracking," formed in opposition to it. After several years in the planning process, a final decision was made by central government in June 2022 to reject the project.

Case Study Background: Great Altcar & Formby

Great Altcar is a small village (~250 people) in Lancashire, around 13 miles north of Liverpool. Directly west and across the A565 trunk road is the town of Formby (~20,000 people). While each have their own set of senses of place, residents from both communities had some shared sets of place connection and felt they were close enough to the project site to be impacted. In Great Altcar, houses and farmhouses are dispersed along the only road that curves through the fields. Nearly all of the land and property in the village are owned by the Leverhulme Estate and tenanted out to local farmers. There is no bus service that runs through the community, nor is there a village hall—the one that did exist is now rented out by a private business. The only space for social gathering is a small church that sits near the "center" of the village, a small row of houses that were initially built as council houses. The community sits on a region of the Lancashire Mosslands, locally referred to as "the Moss." The name comes from the area's peatland heritage, which consists of "lowland raised bog habitat" which has shaped "the region's culture, language and development" (IUCN National Committee United Kingdom 2022).

Formby residents have more access to amenities than those who live in Great Altcar. The town is coastal, and residents of the area expressed their connectedness to the beach, sand dunes and pinewoods, as well as specially designated SSRI, RAMSAR (wetlands of international importance), National Trust and Greenbelt areas. Across communities there is a strong connection to the wildlife, particularly those that are rare or endangered—the natterjack toad, sand-lired squirrels, and pink-footed geese. The shale exploration license for Great Altcar was issued to Aurora Energy Resources Ltd. on July 1, 2008 and a planning application was submitted in 2019. Two local resident organizations opposed this development, Frack Free Formby and the Moss Alliance. Eight months after the England moratorium on shale gas was announced (November 2019), Aurora withdrew their application for shale exploration (July 2020). As such, neither the proposed site in Great Altcar or Woodsetts ultimately moved forward.

Data Collection

Ethnographic research was conducted in both communities, through participant observation, semi-structured interviews and document analysis (Marshall and Rossman 2016). From September–December 2019, Ryder spent just over a month in Formby and Altcar, visiting environmental sites, attending community social activities, and observing meetings. In total, the authors conducted interviews with 27 residents. In Woodsetts, Devine-Wright traveled to attend the June 2019 Planning Inquiry. In addition, between February and March 2020 Ryder spent just under two weeks in Woodsetts interviewing residents, walking the footpaths and visiting the proposed exploration site.[1] In total, 18 Woodsetts residents were interviewed. Furthermore, Ryder was engaged in the local Woodsetts Facebook group and has observed community interactions and information sharing through digital spaces. In both cases Ryder relied on snowball sampling (Biernacki and Waldorf 1981) for participant recruitment. She also knocked on the doors of residents in the closest proximity to each proposed site to try and gain perspectives from the nearest residents. Nearly half of interviewees were older adults, with around 30 percent of those from Great Altcar, and 78 percent of interviewees from Woodsetts

[1]The intention was always to spend more time in both communities but particularly Woodsetts. However, the first visit by Ryder ended the week that the UK began its first lockdown in the midst of the COVID-19 pandemic. As such, researchers were not able to engage in fieldwork to the extent initially planned in the proposal yet employed remote methods (e.g., social media engagement) to remain connected to each case.

Table 1. Types of Interviewees

	Altcar	Woodsetts
Residents	18	7
Resident Campaigners	3	6
Local Councilors	8	5
Total	27	18

Note: These numbers do not add up because 2 individuals serve as both local councillors and resident campaigners.

identifying as retired. In addition, men are slightly overrepresented, making up around 60 percent of our interviewees (27). Of the 45 individuals interviewed, participants represent viewpoints from local government, residents actively involved in anti-fracking campaigning, and residents who faced potential impacts from fracking but were not involved in government or campaigning (see Table 1). Overwhelmingly, individuals we spoke with were opposed to shale exploration. In Woodsetts, there were no interviewees that supported the practice. In Altcar, three interviewees supported shale exploration, though one still did not support the locally proposed project due to place-fit discrepancy (see Devine-Wright 2011a). One Altcar resident neither strongly supported or opposed the local project.

Data Analysis

Recorded interviews were transcribed and uploaded into NVivo for analysis. In Nvivo, key patterns in the semi-structured interviews were developed in early stages via memos and initial coding. Thematic coding (Rubin and Rubin 2012) was used to explore questions related to place-based concerns about the project and risk perceptions. In an effort to achieve triangulation via qualitative data (Patton 1999) we also incorporated participant observation, and included informal interviews and casual conversations with non-participants. By drawing on multiple sources of data, triangulation of multiple methods enhances the quality and credibility of the analysis (Flick 2004; Patton 1999). By combining participant observation notes, interviews, and conversations with residents we are able to better corroborate perceptions and experiences, and check the accuracy of our own observations, improving data validity. Research notes were recorded daily throughout the course of site visits, and were reviewed in an iterative fashion during data analysis to ensure the validity of the developing coding scheme. Combining these methods helped to inform a deeper understanding of local, place-based concerns related to the underground.

Findings

The Role of Underground Landscapes in Shaping Senses of Place over Time

Our first research question is focused on how underground landscape figure into peoples' senses of place. In both communities, residents' understandings of the distinctiveness of their local place was tied not just to aboveground rural landscapes, but also to local histories of material underground interventions, as dominant local workforces transgress the surface plane.

Coal histories & senses of place in Woodsetts. In Woodsetts, the underground exists—both figuratively and literally—as a passageway to the past. The area has a rich history to which the underground connects residents. For example, one Woodsetts interviewee highlighted its historical, cultural, and social meaning:

> *There could be information underground that could be resurrected or brought up to the surface that would increase our knowledge of how our ancestors lived…I don't know if anybody's told you about Anston stone, about that being part of the Houses of Parliament?…So there's history as well…There are connections with Dinnington, where my daughter lives, and old Anston…Why spoil the possibility of one day somebody going really deep down and finding something? – Woodsetts 14*

For her, Woodsetts' underground represents both a time capsule and vault of knowledge that locals should be entitled to explore. In addition to Anston Stones, the area's coal mining history is a key aspect that informs locals' place identity. Two interviewees were former miners and nearly all the residents we interviewed mentioned family members that worked in the mines:

> *[Woodsetts] is a mining village. My father-in-law, he was a miner, and the majority of houses, as you walk on Gildingwells Road, I would say probably 80% or 90% of the men that live there were all miners. – Woodsetts 7*

> *We're a coal mining area, majorly…And obviously that fed everybody as in, their fires heated everybody locally, and employed a lot of people and quite a dangerous job I imagine. – Woodsetts 10*

> *My husband's dad was a coal miner, his dad before him was a coal miner… His dad died quite young because of the effects that coal mining had on his lungs. – Woodsetts 14A*

One interviewee said that he and his brothers worked the mines just as his dad, grandfather and about 70–80 percent of his community did. While he did not regret it, he lamented that they did not know the risks. A former miner's wife recounted being firmly in favor of the mines, describing how the industry is integral to her identity:

> *I used to be very quiet until the miner's strike in '84, then I got very militant. I don't take no crap now, I tell them straight. I went on big marches and that. So yeah, if I believe in something I will fight all the way. Same as I don't agree with this [fracking]. – Woodsetts 13A*

This complicated local history is part of the lifeblood of the community, and is the lens through which many community members see, experience and understand the day-to-day village life both past and present. But it is not only through personal experiences and social connections that this industry imprints itself on locals' understanding of place. Some residents discussed the interconnectedness of the subsurface and surface landscapes and how they have changed the esthetics and uses of the area over time:

> *You could argue that the landscaping that's been done as a result of coal mining and as a result of dust heaps and things, that it's made everywhere look more beautiful. But that's surface. – Woodsetts 14*

> *We could see from here could see one, two, three, four pit tips…But in the time since the mines closed in the 80s, a lot of those tips have been flattened out, grassed over, made into country parks or into nature reserves… – Woodsetts 4*

In Woodsetts, the rolling, grassy mounds which characterize the surface landscape they love are actually remediated waste piles from the mines. While the industry is inactive, community group identity is rooted in a historically dominant industry that has endured both materially and socially. This supports existing scholarship showing that in places with a dominant industry, industry forms an important aspect of collective group identity which is linked to work-identity (Harner 2001; Wester-Herber 2004). Furthermore, this demonstrates how work-identity (1) can be rooted in activities which take place in and are dependent upon a distinctive underground landscape and (2) can endure, informing senses of place over a long span of time (see also Bickerstaff 2012). The collective significance of the coal mining history in Woodsetts is that it connects residents to both people and landscapes, demonstrating that place distinctiveness and senses

of place are derived not only from surface relationships but also from connections between the surface and underground, and below-ground relationships. Thus more holistic understandings of "place" transcends the surface plane to connect above- and below-ground spaces.

Generational farming & senses of place on the "Moss". Residents' senses of place in Altcar are also dependent on relationships and understandings of the underground. Here, the perceived fabric of the community is rooted in farming practices that connect the soil and surface. The village of Great Altcar and the surrounding area are often commonly referred to as "the Moss," and the bog properties are an essential part of senses of place on the moss. For example, it creates the habitat for waterfowl that gives the area designation as a RAMSAR site.[2]

> *Some of the geology around here, because it is a very peat-based land, people are worried about [shale gas exploration] ruining that as well. Formby has got a RAMSAR site…it's like a special ecology site…They're very few and far between in the world…And also several sites which are SSSI, sites of special scientific interest…That is the character [of Formby]….It's a wetland area which has got international importance and water fowl habitat – Altcar 6*

Additionally, agricultural intervention across the decades has meant the peatbog has been drained and dried out to create productive farmland soils that are vital for local livelihoods and as a food source for UK markets. As a point of pride, several residents pointed out that potatoes that grow in the fields around Altcar are used for the well-known Walkers crisps. This highlights how local residents perceive the area's farming practices as one that serves a broader purpose nationally and needs to be protected:

> *The agricultural land we have is of regional significance, national significance for farming…We'll need it in the future. We need to preserve it. – Altcar 9*

Many of the farmers who we spoke with were part of multigenerational farming families, and their reliance on cultivation influences how their formations of "place" include conceptualizations of surface and underground space as connected parts of one system. This does not just inform their livelihood but it also shapes their understandings of and attachments to the village, their ancestors, and the land, both past and present:

> *It [farming, this place] flows through my veins. I mean we've been here since '49, so I was born, I lived over there [house next door] and I've lived here a bit, and I'm going to go back to live over there. – Altcar 21B*

[2]A RAMSAR site a designation given to wetlands of international importance.

> *I lived about five miles down the road. I was born five miles down the road. Been a farmer all my life. We're just arable farmers…I'm the third generation on the farm…. – Altcar 14*

This history of generational livelihood dependence on farming practices where the underground and surface spaces are intrinsically connected is an important aspect of place identity in the community; and, similarly to how housing built up around coal mines around Woodsetts, the village of Great Altcar was built up around farming:

> *Most of the site cottages were tied to the farms and the farm workers that worked there lived in them, probably 40 or 50years ago. – Altcar 15*

Again, we see the endurance of work-identity as a key aspect of senses of place for farmers in Great Altcar (see Harner 2001), though, in this case the agricultural industry—while shrinking—remains active. In addition, this case establishes clear connections between life and landscapes below and above ground, where farmers often do not draw a distinguishing line between the two.

Further, the importance of the underground in forming senses of place is demonstrated through the use of the peatbog characteristics in the enduring name of the area. These bogs are important as they provide the capacity for local waterfowl and protected sites—which were frequently mentioned in describing the character and connection to the local place—to thrive. In Great Altcar we see how the properties of the peatbog become an important aspect of "place," in terms of how the area is talked about, the connection between ecosystem and supported water fowl, and how it is quite literally where crops that sustain local livelihood and connect farmers with their family across generations take root. Here, residents' relationships with the subsurface mediates their relationships to the past, present and future, both locally and at a broader national scale. Furthermore, the connections to the bog developed over time become the basis of local sets of knowledge about the moss.

Place-Based Knowledge & Expertise on the Local Underground

A second dimension of senses of place that is important in the context of this research is how people engage with place through knowledge, developing epistemic bonds (Castro 2021). In this section, we aim to understand what knowledge community members see as relevant, and what actors are seen as possessing trustworthy, place-based knowledge of the subsurface across the case study communities.

Interviewees believed that there were a lot of unknowns and uncertainties tied to underground interventions, which made them wary of industry claims that shale exploration was safe or that risks could be properly addressed. Instead, by and large interviewees tended to rely on information from others in the community they trusted as well as local experts they knew more personally. In addition, interviewees understood shale risks by drawing on place-based, experiential sets of knowledge of the underground that they and other distinct sets of community members possessed.

Coal miners as local underground experts in Woodsetts. In Woodsetts, former mine workers are regarded as having more intimate, experiential knowledge of the local underground. As such, residents turned to those who had lived experiences of working in the mine pits as crucial sources of information for assessing subsurface risks and uncertainties:

> *We had lots of people who were originally in the [coal] industry wanting to give us information about, 'Do you know what's underneath your feet? Have you seen what's underneath here? There are seams underneath these and they're going to drill through these seams and we worked those seams.' – Woodsetts 4*

> *We have met ex-miners who have said we don't know how safe those shafts and things are, we don't even know where they all are. So they've raised the concerns of what on earth is going to happen. – Woodsetts 3b*

Thus, for some Woodsetts residents, the concerns about the unknown subsurface risks—voiced from those who have actively worked in the mines—made it difficult to accept the operators' claims about a lack of risk:

> *They [the operators] say, "Oh, we can safely drill through [the mines]; there'll be no issue." Do you know what's there? Is it methane gas that's trapped in them, is there water? You don't know. So, we don't know. Some people's houses have got mineshafts under, lower down. – Woodsetts 5*

The generalized concerns about uncertainties and unknowns in shale interventions (Partridge et al. 2019) were heightened for Woodsetts residents as a result of unknowns and uncertainties associated with energy infrastructure previously abandoned in the local underground. In response, Ineos confirmed that they would be drilling through the mines, but stated that this is not likely to affect subsidence (INEOS Shale 2017).

Still, Woodsetts community members point to remaining questions about existing mines—their location, their stability, and their safety—which make it difficult for them to believe that a technical knowledge of fracking would be sufficient for assessing risks.

Farmers & geologists as local underground experts in great Altcar. The historical dependence on farming as the predominant source of livelihood on "the Moss" suggest that farmers in Altcar possess important sets of landscape knowledge that spans across the surface plane:

> *My husband and my sons, you know, they've got a real link to the land… My husband knows every inch of those fields, he knows how the drainage system works, he knows what fields will produce…it's that knowledge that's gained from his father from his grandfather, from managing and working that land. It's a long history of information. – Altcar 21A*

Through place-based, historical and experiential knowledge, farmers in Great Altcar have a clear understanding of the local soil and subsurface, discussing, for example, local drainage issues, the relationship between soil states and crop yields, and problems with infrastructure placed on top of mossland:

> *A lot of it's reclaimed mossland, so it's all drained and it's all very low lying, so it's getting wetter because it's drained by pumping stations…This year we've lost quite a lot of crops because the fields have flooded…Altcar used to flood regularly before the pumping stations…I don't know how many times they've had to rebuild the church, because the church just used to sink, and all the houses there were only built in the sort of mid-late 1800s when the pumps came in. Because up to that point because it was regularly flooded, the houses used to deteriorate and need rebuilding. – Altcar 21*

The physical properties of the land have thus had significant implications for farming as well as building. These place-based understandings are rooted in generations of local relationships and experiences of place that include the surface but extend seamlessly into the underground, particularly through agricultural practices. As such, community members come to rely on the farmers for information:

> *[We] talk to the farmers and then of course if we talk to them, we tend to get information from them, you know, a couple of the local farmers that we've known forever. – Altcar 15*

In addition to farmers, the importance of those with technical knowledge about local geology informed residents' risk concerns, namely the increased potential for seismic impacts linked to shale gas extraction:

> *We had a geologist who brought up all about the geology of the area and things like that…We've also got several fault lines as well in this area… – Altcar 2*

Thus, the place distinctiveness of the local geology—as identified by locally based geologists—led to place-based concerns about the impacts of drilling where residents were left with many questions:

> *The people who know the geology here [say] there are vertical fissures…So you could be potentially opening some…How would you know whether you've opened up a fissure that goes into the aquifer; how would you know that you've done that before there's something major happening, you know? – Altcar 6*

Overall, the local and experiential knowledge of the connections between the surface-subsurface properties of the moss in Great Altcar were significant for local residents in evaluating the susceptibility of the local area to induced movement. Through a reliance on locally trusted sources who possess both place-based knowledge and a more technical knowledge of the underground, Altcar interviewees find support for their risk perceptions of the impacts of drilling that are tied to the village's unique geology and soil composition.

What is demonstrated above in both communities is the reliance on place-based knowledge of trusted, locally based, "alternative experts," (Chailleux 2019) when it comes to developing more clear understandings of the characteristics of the local undergrounds, and its importance in terms of risks related to shale gas exploration. Community members drew on their own experiential knowledge and sought out information from locals who possess both place-based and technical knowledge about ecology, geology, soil, and, in the case of Woodsetts, coal mining practices. These knowledge sets were developed through material, generational experiences of working in and with distinctive underground places, and encompass localized understandings of the connections between surface and subsurface in creating place. Further, when there was a lack of expertise amongst community members, campaign groups in each community would raise funds to hire experts within the broader region to conduct further studies (i.e., on ecology, traffic, and noise), thus fostering their own spaces of knowledge exchange and creation. Essentially, local residents produced "counter-expertise" (Cantoni 2022), through experiential, place-based knowledge of the local underground landscape. This was crucial in shaping community risk perceptions around the impacts of shale gas interventions. Their challenge to the primacy of industry expert and scientific knowledge, as well as hierarchical approaches to evidence

(Parkhurst 2017), is rooted in place-informed risk perceptions. These risk perceptions are informed by local senses, experiences and understandings of place-specific features of communities' local landscapes—which include both surface and underground spaces.

Local Undergrounds & Place-Informed Risk Perceptions of Shale Exploration across Space and Time

Finally, we aim to understand how meaningful connections to, and place-based understandings of the underground inform community risk perceptions. Residents in Altcar and Woodsetts share some similar concerns about shale exploration *impacts to place*, including risk related to community stigmatization, loss of financial value, esthetics, and "personal attachment to land" (Wester-Herber 2004) (114). For example, several crucial and shared concerns across both communities were (1) impacts to wildlife, (2) industrialization of the countryside, (3) impacts on housing values, and (4) community place change. Still, interviewees from Woodsetts and Altcar had locally specific concerns rooted in their respective senses of place that drove them toward these mutual concerns. Further, interviewees situated the generalized risks of shale exploration within the distinctiveness of each respective place; noting potential local and regional pathways for surface and subsurface water contamination and describing how the physical surface and subsurface conditions of each place might exacerbate the potential short and long-term risks of shale exploration. While resident concerns span across both the surface and subsurface planes, it is crucial to recognize that many of the surface-level concerns described above are actually the product of fears about how what happens underground in shale exploration leads to potential consequences on the surface. In particular, seismicity and subsidence transform underground risks into concerns that are relevant and visible on the surface.

Local undergrounds & place-informed risk perceptions of Shale gas in Woodsetts. Woodsetts interviewees' intimate connections with the area's coal history—coupled with concerns from some who had worked in the mines—meant that the existing abandoned coal mines were at the forefront of their concerns about the risks of shale exploration locally:

> *We're worried about, even the test drilling, because it goes down three kilometres, and going right down through existing mineworks that already run under these houses. – Woodsetts 3a*

> *Here there's lots of old mining works underneath…they are really concerned that we will have earthquakes because of the drilling. – Woodsetts 12*

As indicated, residents perceive there to be increased risks with shale exploration because of the existing underground and surface structures. This includes concerns about how the interactions between shale exploration and the hollowed out mining works might subsequently lead to surface-level impacts to people's homes:

> *Our bungalows are built on like a raft, because there's lots of mineshafts under here, and I don't think anyone is sure where they are. So we don't know what could happen. And I don't think they know either. – Woodsetts 7*

In particular, residents worried about how induced seismicity might be especially risky given the existence of the abandoned coal mines, and, how ground movement might create surface damage through subsidence like coal mining had caused in the past:

> *The pressure that they're going to be drilling at, is it going to cause any movement underneath the bungalows? Is it going to cause any cracks? Is it going to cause any bungalows to start subsiding like the [coal] pitch used to? – Woodsetts 11*

Residents see technological risk in the underground as connected to risks to surface structures and landscapes. This includes both physical damage to the surface, and potential socioeconomic impacts in the village:

> *They [shale operators] come underneath and is it going to trash your foundations and cause subsidence, and will my insurance go up and will I be able to sell it if I want to sell it? Because all those sorts of things possibly it's going to affect everybody in the village. – Woodsetts 10*

Residents possessed heightened awareness about the potential surface-level impacts of underground activities across the scale of the entire village and the localized region. This is demonstrated, for example by the potential impacts of water contamination:

> *The biggest risks that we anticipate are the local pollution, pollution of the ground water feeding into the wells and the springs that feed that side of the village and out into the local environment, and the water table leading to Worksop. – Woodsetts 4*

In thinking on the potential impacts of shale exploration on abandoned coal mines, residents' show how their understanding of material, place-based underground risks directly inform their surface-level concern about the risks of localized physical and social place disruption aboveground. Residents developed concerns about perceived threats

to place identity and place disruption that would occur both immediately and in the long-term future as a result of the surface damage from seismicity and subsidence if fracking moved forward. In long term, the subsequent impacts of fracking—both below and above ground—could become so extreme that their life in the village would be completely disrupted:

> *They've reinstated a lot of the areas where the mines were, where they've grassed them and treed them, and you've gone beyond that sort of effect on the countryside. But now we've gone full circle, we look as though we could well be going back there. – Woodsetts 6*

For some residents, this brought up conflicting feelings about whether they would want to or be able to leave a place they call home, and whether or not they would be able to sell their houses given the threats of seismicity and subsidence:

> *I don't think we could leave, because it think if we do get this coming into the village, I don't think we'll be able to sell our properties. I don't think people would want to buy them, knowing what could potentially happen. – Woodsetts 7*

> *We built this house, literally, we built it, my wife and I. So, it'd [moving] be the hardest thing in the word. I've just told you what my history is with the village…That's one of the reasons I've fought so hard, you know, and put so much time into it, is I don't want to be pushed out. – Woodsetts 1*

In the long-term, beyond the proposed shale exploration, one resident noted that they recognize that this is unlikely to be the last energy proposal the village may see, with further potential underground interventions centered on the place's coal history:

> *We've had it [local area] returned from the blight of mining and we saw this [shale gas] as a return to the blight of another extraction process…We know now the seams that have been worked that they're going to drill through. And it has awakened with us that if they don't find any shale gas there, there is an issue they might want to acidize the coal beds to get coal bed methane out. – Woodsetts 4*

Given the region's past industrial use for coal mining, residents were particularly fearful that the character of the place—now seen as idyllic countryside—would be re-stigmatized (Wester-Herber 2004) as an undesirable place to live through shale gas fracking. For residents, a threat to

"place" from fracking was also a threat to community and to place-based aspects of senses of self. These threats originate from perceived risks related to underground interventions, and the way that these subsurface risks—particularly seismicity and subsidence—are connected directly to multiscalar, surface-level impacts ranging from damage to houses, housing values, then environment, and the desirability and character of the community at large.

Local undergrounds & place-informed risk perceptions of Shale gas in Great Altcar. Altcar residents' conceptualizations and experiential knowledge of the underground informed their approach to the proposed shale project. Residents believe the geology of their local area makes it more likely to be susceptible to seismic risks than other locations, due to the existence of vertical fissures and the instability of the local peat moss soil:

> *The amount of earthquakes. This land, as I've said, it's peat moss, it's not stable and if they start causing earthquakes here, old houses like this won't withstand a lot of that. – Altcar 19*

This was particularly troubling when residents reflected concern about what unknowns surround lateral drilling, particularly as depending on the direction of the drilling it could theoretically extend under part of the nearby town of Formby:

> *Another concern is…with the earthquakes. Because I mean it's the lateral drilling as well…That's why Formby [residents] are concerned about it, because it's going to go underneath them…I mean we don't know do we, just where it would go. – Altcar 15a and 15b*

Given the distinct properties of the peatbog, residents' understand the "Moss" as more susceptible to movement and fluidity than the ground might be in other places. This, coupled with the knowledge that (1) there are vertical fissures in the local geology and (2) that lateral drilling was technically capable of extending under a nearby town meant residents developed increased place-based concern about potential seismicity. For example, one interviewee recognized that technical calculations for shale exploration might vary depending on soil properties in a given time, suggesting that data collected to inform seismicity estimates reflected abnormal ground conditions:

> *The ground's very soft. There's lots of peat layers around here…It comes up in many applications that as that gets wet and it shrinks it dries out you get a lot of movement…Worry for me is they [Aurora] did the ground condition*

> *surveys in late 2017, which was a very dry winter…There's a few applications that have come in based on the ground conditions that year and I think that… it's going to get a lot worse than that. – Altcar 7*

Hence, familiarity with existing soil properties and underground conditions, coupled with existing knowledge of seasonal local weather patterns and abnormalities led to concerns that the operator's data might not accurately reflect what is needed to stabilize the ground around the project site. Beyond seismicity, concerns about the long-term impacts of exploration that connect underground and surface risks include the potential pollution of groundwater:

> *I think the logistics of getting all the water in and all the water out will leave a lot to be desired. You've got to pump an awful lot of water down there and it's wastewater coming out. I just think that's a big concern really. What they'll do and what they're actually disturbing down there and fetching up. It's bound to be polluted in some sort of way. – Altcar 20*

> *If they had any big leak there it would get into the [Liverpool] bay and through the [River] Alt and… So if it went wrong, the potential for this to spread or not be contained is significant, especially if there's several well sites there. – Altcar 7*

Another worry about potential contamination of groundwater was how it might have a negative impact on wildlife habitat, particularly the protected pink-footed geese who migrate through Great Altcar:

> *We get massive flocks of wintering geese feeding on these fields and if they're starting to take contamination [polluted water run off] in, you're going to decimate the flocks. – Altcar 19*

Further, a key risk area for local farmers was how groundwater pollution might potentially pollute the soils where they grow their crops, an issue which came up during surveying:

> *When they did the survey for this fracking, that has caused us endless trouble. Field drains that don't work, water bubbling up where it never used to bubble up…And before [the survey] you never saw that, never. – Altcar 18*

There was concern about what long-term impacts could occur to the farming community in Altcar if shale gas activities led to the contamination of local soils and groundwater used to produce food. Farmers and non-farmers alike wondered about the long-term ramifications of this scenario, well into the future:

> *Some people have said, "Well, what happens if it pollutes the ground?" As a farmer we've got to assure producer, so we've got to pass all these tests. So, if the soil is contaminated you won't be able to sell your produce. – Altcar 14*

The scale of impact could be great, as contamination of groundwaters and soil becoming affiliated with the community's produce could significantly damage place branding, such as when undersea oil spills in the Gulf of Mexico came at a large economic cost to workers in Louisiana's seafood industry (Morgan et al. 2016; Sandifer et al. 2021; Upton 2011). Residents feared what contamination could mean for the future of the local farmers and their livelihood:

> *We provide so much of the food for the UK… if the supermarkets decide that they don't really want to be associated with selling stuff from Lancashire, what happens to the farmers? – Altcar 10*

> *This site is on farm land, grade I, agricultural farm land, so where are we going to get food from? We're an island, and if we cut ourselves off from everybody, where are we going to grow food? – Altcar 2*

Thus, a key concern around shale exploration in Altcar is the long-term impacts of the practice of food safety and quality, a primary source of local livelihoods, especially if the industry were to scale up locally in the future like it has in the US. The potential risk to the quality and reputation of local agriculture is seen as a surface-level impact that materializes first within the underground. There, contamination of the soils and water farmers rely on for their crops to grow would threaten local livelihood as well as communal senses of place, as these crops connect the surface and subsurface that facilitate much of the residents' senses of place through relationships to neighbors, family, local water fowl and the fields. Finally, these risks span across space and time, putting the short-term benefits of the practice for shale developers at odds with how community members envision the future. One farming family points to how their livelihood orientates them to long-term thinking:

> *B: I always have it sat at the back of my mind that the next generation will get the use out of it.*

> *A: What's the old saying, live as though you're going to die tomorrow? Farmers live as though you're going to live forever.*

> *B: Everything you do on a farm is that long-term, you know, should I drain that field, or do this and plant that? You know, in 20 years' time, you know someone will be having the benefit of that. – Altcar 21 A & B*

Thus local agricultural practices incorporate future visions of place, and fit these activities into that vision. Shale exploration disrupts this, creating negative visions of future place change.

Finally, the impact of shale gas was also tied to the long-term, localized climate risks that could exacerbate existing flooding issues. These concerns link back to the conditions of the soil and the potential impact of climate-driven place change on the subsurface and local agriculture:

> *The climate is changing…When it's getting wetter it's getting very wet and some of the places are nearly unfarmable…You can't harvest in September when the place is back to a bog…It's worthless…They keep having to drain it and the peat is shrinking, so there's only so much peat there and it'll become, maybe in the next 30 years, nearly unfarmable in places. You can see where the fields are sinking. – Altcar 20*

Overall, Altcar residents believed that shale exploration had the potential to disrupt and threaten the village's agricultural heritage and future, a relationship that relies on the health of the connected underground and surface spaces and which has already become more precarious in the last few decades. Like Woodsetts, residents shared concerns about the potential for physical damage and drops in housing values to disrupt the character of the places. Yet, these immediate concerns were rooted in very different sets of senses of place and place-based knowledge. Further, long-term concerns were also rooted in underground place distinctiveness. That is, fears in Woodsetts were related to the ways that an already mined landscape might impact future energy infrastructure projects, while in Altcar concerns were more focused on potential flooding as a result of the future impacts of climate change on an area where the soil is already naturally too wet. Thus, these cases illuminate the importance of understanding how similar fears can develop about possible place disruption from the same technological interventions, including threats to place and community, while the motivations and drivers of risk perceptions are often tied to the distinctive local characteristics of and relationships between the subsurface and surface landscapes across time.

Finally, it is worth noting that implicated in the fears of place disruption in both communities are concerns about place change related to time, space and scale. Perceived risks are about the capacity for the

practice to disrupt and change places through changes in materiality across underground and surface spaces, particularly if the scale of development were to increase. Interviewees' risk perceptions are tightly tied to senses of place and place identity that have endured over time, the future of which are threatened. This demonstrates the complexity of human-underground relationships in the "Anthropocene," which Yusoff (2017) argues encompasses our subterranean past, our present subsurface relations, and our future underground. Given the pursuit of several energy infrastructure projects that rely on subsurface intervention, such as land-based carbon removal with underground carbon storage, geothermal energy and underground heat storage, hydrogen extraction and storage, subsea carbon disposal, ground source heat pumps, lithium mining for electric vehicles, the underground is an integral part of our collective energy future. As these technologies are scaled up and become more ubiquitous, it will be important to be able to account for and address variations in place-based values and concerns across technologies and interventions depths.

Discussion & Conclusion

To date, little research has focused on the connections between underground landscapes, place and risk perceptions in proposed energy projects. In addressing this gap, we find that together senses of place and place-based knowledge sets tied to the underground are crucial in informing risk perceptions related to shale gas exploration. While residents across both case study communities had some overlapping risk perceptions, their concerns were rooted in very different sets of senses of place and place-based knowledge which include both the surface and the underground as distinctive aspects that together constitute their conceptualizations of their local place. Given this, residents' saw shale exploration as having the potential to physically disrupt meaningful underground and surface landscapes, which ultimately they believed could cause disruption to individual and shared senses of place in each community by negatively impacting the social characteristics of the villages as well.

Interviewees' long-term concerns about the collective futures of their community were also rooted in underground place distinctiveness. In both communities there is a clear sense of fear about rapid change wherein the rural villages are transformed into a more industrialized site, and senses of place are disrupted as the areas become "stigmatized," (Wester-Herber 2004). Yet, as noted by a Woodsetts resident above, for their village this would amount to a re-stigmatization of the village that has undergone changes that are perceived as positive following what he

calls the "blight" of mining. In both communities, the underground is a vital aspect of the connections between local histories and present-day culture in each community, yet it also represents the potential imminent and long-term, localized risks in the context of energy and climate presents and futures.

An important caveat to note is that across the span of this research project, a moratorium on hydraulic fracturing was put in place in England in late 2019. After a brief resurgence of political support for the practice when Liz Truss became Prime Minister and lifted the moratorium in 2022, Rishi Sunak became Prime Minister and reinstated the moratorium just one month later. Leadership changes, coupled with the restructuring of the Department for Business, Energy & Industrial Strategy in 2023, suggests shale gas does not have a future in the UK. However, frequent government U-turns on the practice, coupled with heightened talks of energy security in the wake of the Russia-Ukraine war (a key argument which has been used to bolster support of fracking, see Williams and Sovacool 2019), means it cannot be fully ruled out. Further, the findings of this research are important because they demonstrate risk perceptions in anticipation of underground energy interventions, which, regardless of shale gas, the UK will rely on to meet net zero. This includes interventions such as carbon capture and storage and geothermal energy and storage, both of which at deep depth and in some forms can induce seismicity. Applications of carbon capture and geothermal energy and storage are global and growing—over 200 carbon capture facilities are proposed to be in operation by 2030 (Budinis et al. 2022), while geothermal had direct use in 88 countries by 2020 (Lund and Toth 2021). As these practices continue to gain shares in global energy profiles in the pursuit of net-zero strategies, the relevance of research on place-underground relationships and risk perceptions of underground energy interventions will increase.

These findings strengthen existing research that demonstrates concern about place disruption in shale and energy contexts (i.e., Jacquet and Stedman 2014; Junod et al. 2018) by providing a more in-depth analysis of how specific, localized understandings of the underground inform senses of place and increase risk perceptions on the impacts of shale gas in particular locales. They illuminate the importance of understanding how similar fears can develop about possible place disruption from the same energy interventions, while the motivations and drivers of risk perceptions are often tied to the distinctive local characteristics of and relationships to the underground and surface spaces that comprise the landscape. This strengthens understandings of senses of place by providing a clearer picture of the way conceptualizations of place span

and connect both surface and subsurface spaces, and how the connections between underground activities and disruptions are connected to both subsurface and surface-level risks and impacts.

In the past, potential place-based conflict around risks of energy infrastructure projects were addressed by developers and governments as issues of public information deficit which could be solved through getting the right information out to the public and communities (Devine-Wright 2011b; Wester-Herber 2004). However, this has proven to be ineffective in addressing public risk perceptions and attitudes about proposed energy projects. Wester-Herber (2004) argues the need for "risk" to also (1) be understood as subjective, (2) be expanded to include issues of place, equity, morality and fairness, and (3) include more public involvement in decision-making around risk. Our findings support this, as residents relied on their own experiences and the relevant expertise of community members past and present, to develop place-based risk concerns connecting the potential underground and surface impacts of shale exploration. Similarly to residents facing shale development in France and Poland (Cantoni 2022; Chailleux 2019), interviewees relied on local expertise to challenge existing industry narratives and the processes through which scientific knowledge becomes privileged (Landström et al. 2011; van Zwanenberg 2020). Residents saw industry efforts to downplay uncertainties and unknowns about the impacts of underground intervention (particularly potential seismicity and subsequent surface damage) as contradicting information from their own experiences and trusted sources. Consequently, this further fueled community distrust in industry-backed research and the operator or regulator's ability to know or manage risks appropriately.

Our work contributes to scholarship on the subjectivities of risk, and, that how uncertainty is understood, experienced, and responded to is both place-based and historical (Mehta and Srivastava 2020). We demonstrate how local, place-based, relational, and experiential knowledge and expertise can influence how a proposed underground energy infrastructure project is likely to be perceived. This carries important implications for developers in current and future proposed energy projects involving the underground. This includes the underground interventions described above, as well as aspects of energy projects that rely on the underground at different phases of production and consumption, such as the removal of peat for upland wind farms, the laying of cables and pipelines, damage to peatland from carbon sinks, the burying of batteries, nuclear and other radioactive wastes, underground (and undersea) carbon capture and storage, and the potential impacts of both shallow and deep geothermal energy and heat storage. Essentially, we

demonstrate that policymakers and developers cannot just assume if an energy project is out if sight it is out of mind. Instead, the underground matters and there is a need to ensure that policymakers are not failing to account for this, particularly in regions with underground histories as these communities may be particularly attuned to proposed changes to underground spaces.

As traditional approaches to risk communication that focus on "matters of fact" do not always align with place-based "matters of concern," (Stewart and Lewsi 2017) proposed energy projects moving forward will need to address both place-informed approaches to technical risk and perceived threats to place across the underground and surface landscape. To do so requires a shift in ontology (Devine-Wright 2022) which emphasizes plural and diverse forms of knowledge and views proposed energy sites (above and below ground) as places. This includes a recognition of the politics of the subterranean and verticality, where underground are places of contestation and meaning (Wang 2021). Moving forward, future research should explore: (1) how planning and decision-making processes can better value and account for senses of place and place-based knowledge, (2) authenticity and perceptions of developer strategies of place-making which ground projects in their localities (Devine-Wright 2009, 2011b), (3) how more pluralistic approaches to knowledge-making in energy infrastructure projects might lead to more just, inclusive and democratic practices and decision-making. These issues will continue to be increasingly important as use of the underground to support net-zero strategies "evolves and intensifies," (Gormally, Markusson, and Bentham 2018)—both in the UK and worldwide.

Data Availability Statement

The qualitative data generated by this research is stored with UK DataService Reshare, with safeguarded access. (We are currently updating the data records at the request of the repository but will supply a link to the data when we have one).

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