

## **Fault Lines: Seismicity and the Fracturing of Energy Narratives in Oklahoma**

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**Abstract** Oklahoma is an oil and gas state where residents have historically been supportive of the industry. However, a dramatic increase in seismic activity between 2009 and the present, widely attributed to wastewater injection associated with oil and gas production, is a new and highly salient consequence of development. This research engages Oklahoma residents through open-ended interviews on their experience of and reaction to earthquakes. We use these interviews to characterize how energy narratives emerge in response to conflict between environmental outcomes and economic interest associated with a long-standing industry that is personally important to many in the state. We find that seismicity has fractured the dominant narrative of oil and gas development as important for the state into descendant narratives framing seismicity as a minor problem that will be resolved without affecting the oil and gas industry significantly, as a major problem that warrants opposition to the oil and gas industry, or as a problem that needs to be addressed, but not at the cost of all oil and gas development. Trust and a sense of personal efficacy are important in determining people's reactions, and loss of trust in government is more widely observed than loss of trust in industry.

**Keywords:** induced seismicity; Oklahoma; oil; society

### **1 Introduction**

Oklahoma has suddenly become an earthquake state. The state experienced about 900 earthquakes rated 3 or higher on the Moment Magnitude Scale (MMS) in 2015, a dramatic increase from a background level of fewer than two such earthquakes per year between 1978 and 2008 [1]. In September 2016, Oklahoma experienced its biggest earthquake ever, rated 5.8 by the United States Geological Survey [2]. This earthquake, centered near Pawnee, Oklahoma, surpassed a 2011 5.7 MMS earthquake centered in Prague, Oklahoma, the state's previous record holder. Prior to 2011, the largest earthquake recorded in Oklahoma was a 1952 event rated between 4.9 and 5.7 [2]. This dramatic rise in seismicity has generated substantial interest in causal mechanisms, mitigation techniques, and expectations for future seismic activities in the state. Concerns about the possibility of individual large events join concerns about cumulative damage from the large number of relatively small earthquakes Oklahoma has experienced.

The rise of induced seismicity in Oklahoma and the widely acknowledged link to oil extraction provides an important opportunity to study social response to a negative outcome of energy resource use. Studies of social response to hazards related to energy resource use often identify challenges like unclear cause-effect relationships (see e.g. [3]), lack of institutional trust [4], reduced interest over time after a large event, or low salience for people not personally experiencing harm (e.g. with respect to social disparity of climate change harms, see [5]). Seismicity in Oklahoma is thus an important case study because it is understood as related to energy development, associated with ongoing and persistent events, and widely experienced among residents. Further, while the seismicity hazard itself is effectively new (current levels of seismicity in Oklahoma are far below natural levels, [1]), the causative activity of oil and natural

gas extraction is not. In many other published cases, opposition to projects or industries perceived as causing social or environmental disturbances includes a secondary opposition to newness or perceived threats to residents' historical livelihoods or industries (see e.g. [6-8]). In Oklahoma, by contrast, oil and natural gas activity is common, well understood, and generally perceived relatively positively. Thus, induced seismicity in Oklahoma presents a rare opportunity to evaluate social response to a negative outcome of a socially integrated activity. This project assesses how seismicity as a new and highly salient environmental consequence of oil and natural gas development has affected the relationships of Oklahomans to the environment and to the oil and natural gas industry. We add to social science literature on narratives in energy and environment (e.g. [9-15]) and complement the mainly physical science literature on Oklahoma seismicity (e.g. [16-20]) by characterizing emergent narratives about induced seismicity based on interviews from summer and fall 2016. We focus on underlying assumptions and political implications, concluding with a discussion of how this case study informs communication efforts in other energy-related hazard settings.

## 2 Methods

This research is based on 20 formal interviews with 17 individuals performed in summer and fall 2016. We follow the example of authors like Rolston [21] and Loe and Kelman [22] in noting our personal ties to this case study of Oklahoma seismicity, which contributed to our understanding of the setting beyond the formal analysis undertaken for this work. Both authors have family in affected parts of the state and have participated in both formal and informal discussions about seismicity and wastewater disposal for several years (e.g. [23]). Further, the lead author personally experienced the two largest recent seismic events, the 5.7 MMS earthquake in Prague, Oklahoma (2011) and the 5.8 MMS earthquake in Pawnee, Oklahoma (2016) [2]. Exploratory analysis of online comments on news and social media sites was also conducted. As initial findings were largely similar to those drawn from interviews and because of concerns about using personally identified (public) data without explicit consent from the relatively small number of individuals involved, the analysis is not included.

The purpose of conducting formal interviews with people who have firsthand experience with induced seismicity was to understand details of how individuals' assumptions about and understanding of the oil and gas industry, state regulators, and their environment changed in response to the sudden appearance of a consequence of a locally familiar energy related practice. We emphasize that a shared experience of earthquakes is new for Oklahomans: as one participant noted,

I grew up in Oklahoma, and earthquakes were not normal. [My child] is growing up in Oklahoma too, and to [my child], earthquakes are normal. –“Melissa,” academic

Given our goal of identifying community narratives about seismicity related to oil and natural gas extraction in Oklahoma, we focused on recruiting participants whose personal experiences were likely to contribute to diverse perspectives on seismicity. That is, our interviews were designed to elicit highly differentiated rather than representative perspectives. Our interviews are summarized in Table 1, including pseudonyms used throughout this article.

**Table 1. Summary of Interviews**

Pseudonym	Interview Mode	Affiliation	Experience level	Re-interviewed?	Narrative
Bill	in person	affected resident	retired	no	2
Bob	in person	oil and natural gas industry	senior	yes, by phone	1
Chuck	in person	environmental organization	senior	no	3
Dave	in person	environmental organization	senior	no, did not respond to request	2
George	in person	affected resident	senior	no	3
Henry	phone	academia	retired	no	1
Jennifer	phone	environmental organization	senior	no	3
Justin	in person	student	student	no	3
Linda	in person	affected resident	mid-career	no	3
Mark	in person	government	senior	yes, in person	1
Mary	in person	affected resident	mid-career	no	3
Melissa	in person	academia	mid-career	yes, by phone	3
Michael	in person	media	mid-career	no	3
Rick	phone	industry/government	senior	no	1
Samantha	in person	student	student	no	3
Susan	in person	affected resident	mid-career	no	3
Tammy	phone	environmental organization	mid-career	no	2

Participants were recruited using several approaches: 1) direct outreach to prominent stakeholders in the energy industry, environmental groups, academia, media, and government, identified using Internet searches focused on induced seismicity; 2) convenience sampling based on recommendations of acquaintances, colleagues, and other personal and university connections; and 3) snowball sampling based on recommendations from interviewees. Prominent stakeholders were defined as people who have a history of publicly discussing seismicity and consistently spend time addressing seismicity either professionally (e.g. industry group leaders, oil and natural gas company executives, energy-focused journalists, academics publishing on or teaching students about seismicity, environmental group employees) or personally (e.g. active volunteers).

After our first round of interviews, we assessed our participant pool and focused on recruiting additional 1) young people and 2) residents experiencing seismicity who did not also have a professional interest in the topic. We note that identifying participants from these groups who were willing to speak to us on the record was very difficult, in part because of a persistent stated assumption that they had nothing to say: many people told us that they had experienced the earthquakes and were generally aware of extraction-related seismicity but did not have anything interesting to say, even when we assured them that we were interested in their experience regardless. We note further that our personal affiliations with the state was often the reason potential participants gave for even considering speaking with us on the record, suggesting that trust was important in our recruitment (see e.g. [24]). This recruitment challenge contributes to our sense that while many Oklahoma residents are personally familiar with induced seismicity, public and private speech remain differentiated and many Oklahoma residents are somewhat conflicted about tensions between seismicity and oil and natural gas extraction activities (Section 4).

Ultimately, 17 individuals agreed to speak with us on the record about their experiences with and perceptions of induced seismicity in Oklahoma. Of these, 12 agreed to be audio recorded. Those

who did not consent to audio recording expressed concern about privacy but agreed to detailed note taking. Interviews were conducted between June and September 2016 either in person (author preference) or by phone (due to logistical constraints or interviewee preference, see [25]). Interview questions were designed to invoke experiences with earthquakes and their general views of their local communities. Specifically, we asked questions like: What is important about your community? Have you personally experienced an earthquake? Do you feel conversations about seismicity are important? Has the way you view the energy industry changed in response to seismicity? Though framed around earthquakes, the interviews were open ended and conversational, and participants were encouraged to speak about topics that were important to them. For example, a college student spoke of the moral juxtaposition between searching for a job as a chemical engineer while dealing with anti-industry animosity, and a homeowner spoke of her experience making an insurance claim for earthquake damage repairs. While the small size of our study is a limitation and our work is intended to be descriptive rather than representative, we believe our effort to recruit participants from highly varying backgrounds increased the chance that we uncovered a range of assumptions about induced seismicity.

In addition to our 17 initial interviews, we re-interviewed three informants between September and October 2016 to elicit their perspectives on the 3 September 5.8 MMS earthquake in Pawnee, Oklahoma's largest recorded seismic event [2]. These three people were selected for follow-up interviews based on their expectations (stated during their initial interviews) that a large seismic event would meaningfully change either their own or others' perceptions of the industry. A fourth participant who had made similar statements did not respond to requests for follow-up. During this follow-up interview, participants were asked whether the Pawnee earthquake had affected their outlook or the outlook of people they interact with on induced seismicity, whether the response to the large earthquake was what they would have expected before the earthquake, and what their personal experience of the large earthquake was.

Both transcripts and interview notes were managed and coded using thematic coding techniques in NVivo 10. The two authors independently conducted initial open coding passes, then discussed and reconciled major code themes. The corresponding author then recoded interviews according to these themes, which broadly include: appeals to authority, environmental justice, personal efficacy, socioenvironmental impacts, and trust.

### **3. Results**

In this section, we introduce several narratives about induced seismicity in Oklahoma that emerged from our interview analyses, describing what we heard from our interview participants (see e.g. [15]) through paraphrasing, synthesis, and direct quotation. Theoretical context and implications are discussed in detail in Section 4. Our research suggests that a relatively homogeneous narrative of general acceptance of or support for the oil and natural gas industry prior to the advent of induced seismicity has split into at least three narratives with different public policy implications in a post-seismicity world. Specifically, some informants characterize seismicity as a minor issue that will be resolved without significant harm to the oil and gas industry. Others see seismicity as a major and unacceptable issue that is not being sufficiently addressed. A third group sees seismicity as a moderate problem that merits regulatory attention

but, at least at current levels, is possibly an acceptable tradeoff for the benefits of oil and natural gas.

### 3.1 Narrative 1: “Lesson learned, let’s move on”

*Oklahoma is an oil and gas state, and we have industry experts here who have the situation under control. Earthquakes started happening more often. The link between a long-time water disposal practice and seismicity was not clear at first, but industry worked closely with regulators and established that link. Lesson learned. We note that Oklahoma has natural seismic activity, and we think complete cessation of injection is unwise—it might even create more seismicity based on pressure changes. Industry has reacted responsibly in supporting regulators and reducing injection rates. The problem is real, though maybe a little overstated. We live here too, and we also dislike earthquakes. But the right people are paying attention, we don’t want to hurt the economy, and we expect the issue to resolve itself over time given market conditions.*

This first narrative (also referenced as Narrative 1 in this article) describes induced seismicity as a real but relatively minor problem that will be resolved without too much harm to the oil and natural gas industry. Interviewees spoke of enterprise risk and the fact that oil and gas industry affiliates—and decision makers in particular—live and work in the communities where there is activity and thus have multiple levels of vested interest in reducing the problem. In our participant group, this narrative was observed among those with the most relative power over ongoing activity and regulation (industry, government, and consulting academic affiliates). Given this affiliation, it is not surprising that those subscribed to this narrative spoke of the existing response to seismicity as collaborative and effective, if a little slow to emerge:

It really took a while for everybody to figure out a possible connection [from the earthquakes] to oil and gas. And then more specifically focusing on disposal of waste water. And so it’s been really interesting to be a part of and truly not having the science or the understanding to back up what was going on and to balance the public perception of what it was with the reality that we didn’t really know and...this just was not something we had anticipated. We had been injecting salt water disposal wells in the state for seventy years, you know, so that just wasn’t an issue. —“Rick,” industry/government

This narrative is an example of an “expert” narrative, which often emphasize technical sources of knowledge and authority in decision making (see [26]). Interviewees in this group frequently referenced technical conditions and ongoing research, supporting the hypothesis that this narrative relies partly on a sense that the situation is in control, understandable, and accompanied by a clear course of action for individuals. In this case, that course of action is monitoring and waiting, given prior efforts in scientific research and meetings with various stakeholders. Many statements appealing to the authority of technical knowledge and describing the current seismicity state of affairs are in past tense, suggesting a sense that this narrative includes a belief that the problem is essentially solved.

Notable differences between statements in this narrative and others include consistent references to alternative plausible explanations for the seismicity and comments that the damage associated with seismicity has been quite low. Interviewees also referenced external trends they consider likely to reduce induced seismicity, such as the falling oil price's downward pressure on oil and therefore water volumes. Thus, this narrative is supported by both a belief that the industry itself is proactive and a belief that economic forces will tend to solve the problem without substantial action.

### 3.2 Narrative 2: "Earthquakes must not continue"

*Vulnerable people are being adversely affected by seismicity, and we expect the problem to continue—and perhaps to get worse. The state is in the pocket of the oil and gas industry, and we have no faith that our interests are being protected. No one will help us when we need help. The earthquakes are causing significant damage, and it is difficult to convince others how bad the problem really is. We continue to reach out to our communities and put pressure on government and media. If stopping oil and gas activity in Oklahoma is what it takes to fix this problem, that is acceptable. The earthquakes need to stop. Plus, it's not just seismicity that's a problem. We are also concerned about climate change, water contamination, cancer risks, and other issues. We hope that seismicity will be a way to help us have conversations about these other issues as well.*

The second narrative (Narrative 2) shares some assumptions with Narrative 1—most notably, that the oil and gas industry has influence over the state's response to induced seismicity—but introduces other assumptions that are in direct opposition. Rather than characterizing seismicity as likely to get better over time, this narrative assumes it will get worse. Damage is characterized as severe. Interviewees adopting this narrative frequently refer to lived experiences of harm and a sense that both physical and emotional damage are being forgotten. Discussion of concern about cumulative damage from many small events and the day-to-day stress of seismicity is also common:

So the good analogy is like a boxer. You have the knock out punch is the exciting fight that you see, and you get the one knock-out punch and the guy goes down. Well boxers can still be taken out by a whole lot of small punches. Punch punch punch punch punch punch punch, and then they're still down! That's what's happening to our houses here. We're not getting one big earthquake that devastates our community, we're getting little punch, little punch, little punch, constant. 50 in one night. And it's tearing our houses to bits, and nobody is recognizing it, and nobody is admitting that it's happening. –  
"Jennifer," affected resident

As with the Narrative 1 use of technical knowledge to support the overall position that oil and gas development need not be impeded by seismicity, Narrative 2 invokes technical experts to support the overall position that seismicity is only one indicator that oil and gas development should be constrained. Specifically, this narrative assumes that seismicity is associated with hydraulic fracturing and is one of many social and environmental issues that needs to be

addressed, including environmental justice issues related to a perceived larger response to earthquakes in wealthy areas and concern about possible impacts to water quality.

In addition to the technical citations and reference to expert ways of knowing, Narrative 2 interviewees tended to share vivid stories of personal experience. In addition to negative stories about earthquakes, these stories include references to Oklahoma as a home and a place worth protection, as “Jennifer” recounted when describing an interaction with someone who asked why she did not simply move away:

And he asked me, “Well, why aren’t you just moving?” And I said, “Come here.”...And I had him walk out on my back deck with me. And you walk out, my deck is on the second floor. So it’s this balcony area, and there’s two ponds down below you and these woods that go all out, and my barn, and it’s just beautiful. And I said, “Nope.” He said, “You don’t need to say anything. I understand.” –“Jennifer,” affected resident

“Dave” expressed a similar feeling that Oklahoma is worth protecting, but with a different result:

Yeah, I mean I definitely want my daughter to be out of here...I want her gone and I want to follow her. Now that I am full-time trying to change the actual culture of where I am myself personally, it’s had a huge impact...I really just, I don’t know how long I can keep beating my head against the wall...I have no respect for their industry anymore because of what they’ve done to our state. –“Dave,” environmental organization

As “Dave” explained, seeing his home become a place that he does not feel safe in is difficult and might lead to his leaving Oklahoma.

Notably, while some interviewees see seismicity as yet another reason to oppose industry, others became active because of seismicity:

I would say earthquakes are absolutely the reason that I’m an activist now. If I’m an activist now, that’s the reason I’m an activist. –“Tammy,” academic

The population of activists engaged due to seismicity is particularly important because it demonstrates that seismicity actually has changed people’s minds.

### **3.3 Narrative 3: “There’s a solution, right?”**

*Oklahoma is an oil and gas state, and I recognize the benefits that provides to me. I use oil and gas products and value them. Oil and gas provides my community with jobs and economic prosperity. I am proud of my state’s contribution to the country’s economy. Given these benefits, I’m willing to sacrifice some things, and I do not want to shut down the industry for discomfort and inconvenience. All that said, I am worried about the earthquakes. Seismicity is disruptive and annoying, and I am bearing a personal financial and psychological cost because of it. Further, I am afraid: what if it gets*

*worse? Is my family safe? What else might be happening that we don't know about? There must be a compromise solution that preserves the oil and gas industry's contribution to the economy but stops these earthquakes. Meanwhile, I need to protect myself, and I am not sure who is trying to fix this.*

The final narrative we identify (Narrative 3) is notable as not only the most prominent among our small sample of interviewees, but also as the narrative that respondents perceived to be the most common among Oklahomans generally (see Section 4). This narrative contains the greatest tensions of the three, as people seem genuinely concerned about the seismicity but reluctant to oppose oil and gas development:

“At the end of the day,” [a woman at the meeting] said, “What I just want to know,” she goes, “I get it, I’m from here. Oil and gas is important. What I want to know is that when I was at home this weekend, we’re getting ready to have our second baby, and we’re getting the baby’s room ready and we had the crib up against the wall. And I went to hang a picture above the baby’s crib,” and she said “What I want to know, is it safe to hang that picture above the baby’s crib?” –“Rick,” industry/government

Most people in Oklahoma appreciate the jobs and appreciate the, even if I don’t directly work in the oil field, most of my friends do, a lot of people at church do. I know people in the industry. And so I don’t think most Oklahomans, most people I talk to, want a moratorium. They want to figure out “Okay, how can we keep doing this safely without tearing down my house?” And so I think those are the questions I hear all the time is “How can this be done without causing earthquakes? We’ve had oil in Oklahoma for a hundred years, we’ve only had earthquakes for four or five [laughs]. How do we go back to that?” –“Michael,” media

In Oklahoma in particular...most people here are going to love that there’s an American energy source...And they know that it contributes a lot to the economy, but I think there’s always a concern of “Are we keeping our groundwater safe? Are we keeping, you know, guarding against earthquakes?”...But yeah, I don’t think any of [my students] think it’s handled. –“Melissa,” academic

This group noted a reactive stance rather than a sustained response, noting increased public outcry associated with specific seismic events:

[That earthquake] was long and strong enough that I was worried it would do some structural damage...You know, it kind of quieted down. That day or two afterwards everyone talked about it and then it just kind of disappeared. –“George,” affected resident

This public outcry is fundamentally different from that associated with Narrative 2 in that the it does not shift to a full call for stopping development and does not tend to make connections with other environmental causes. That is, an earthquake reminds people that seismicity is a problem and a source of fear that they want to have addressed, but the concern is about earthquakes,

rather than other environmental and environmental justice issues. In addition, Narrative 3 participants tended to discuss experiences of one or a few earthquakes that were exciting until they became inconvenient, whereas Narrative 2 participants tended to describe many, highly disruptive events.

The major question underlying Narrative 3 is, “Is this negative outcome still worth the benefits?” In some cases, interviewees describe oil and gas development as a given to be worked around, and many people reference the connection between their lives and the oil and gas resources they personally depend on. This narrative assumes something can and should be done. What that course of action is, and who can be trusted to define and implement it, is much less clear. Based on our interviewees’ perspectives on their own reactions and the reaction of those in their personal networks, we believe that the third narrative of tension between dislike of earthquakes and desire to preserve oil and gas development in Oklahoma is most common of the three that emerged in our work, though we note that our sample is not representative. The first two narratives of relative lack of concern or relatively extreme concern, however, tend to create more action in the state. We discuss some of the likely reasons behind the emergence of these narratives in Section 4.

### **3.4 Response to the Large September 2016 Earthquake**

Despite predictions by several interview informants during summer 2016 that another large seismic event would dramatically alter the conversation about oil and natural gas development in Oklahoma, we did not detect widespread changes to the narratives observed prior to the 3 September 2016 event. For example, “Mark” noted over the summer that

I think they felt the outcry, you know, that if you had another, if you had a continuing series of four pluses, that it was going to get really ugly. But if you had another five plus? I mean, it could shut down a lot of injection wells. –“Mark,” government

We note, however, that the 3 September event was relatively nondestructive for its size; expectations among our informants are now that a destructive earthquake, particularly one causing a fatality, would trigger a larger reaction among the public. For now, though, we observe relatively little change to the overall industry-tolerant orientation of Oklahoma’s public. As “Bob” noted,

We didn’t even have the newspaper call us... I thought oh, maybe that will get some attention in the newspaper or something here. But I saw nothing!...I had often thought, if we ever had sort of a 5 magnitude, that that would probably get the community to organize a negative message toward the industry. And I, it didn’t happen, and I think why it didn’t happen, there’s really not that much damage associated with that fairly large earthquake. –“Bob,” industry

All three of our post-Pawnee earthquake follow-ups referenced the lower-than-expected damage. While this is a small sample, we note that media coverage was less than expected after the Pawnee earthquake, consistent with our interviewees’ comments. “Melissa” (academia) noted

that the limited response was particularly surprising given the earthquake's proximity to a university with young people present and attributed this reaction to the low level of evident damage. "Mark" (government) referenced a recent deadly 6.2 earthquake in Italy in noting that the limited damage from the Pawnee event was surprising for such a large earthquake and mentioned being afraid during the event, in contrast to his personal experience in prior earthquakes. Based on our initial work and our post-Pawnee earthquake follow-ups, the potential for widespread public outcry exists but is probably more closely linked to damage and harm than to size alone for future events.

#### **4 Discussion**

Seismicity is a real and widely experienced impact of oil and natural gas development in Oklahoma. Unlike many other socioecological outcomes of energy development in communities, seismicity is a new outcome associated with an old industry. Thus, induced seismicity in Oklahoma provides an unusual opportunity to examine community response to environmental and social impacts independent of confounding factors associated with the newness of an industry that are often observed in studies of unconventional fossil fuel development in communities that did not have a prior recent history of industrialization. The rise of induced seismicity as a widely experienced phenomenon in relatively industry-dependent communities, coupled with the recent experience of Oklahoma's biggest-ever earthquake, provides an opportunity to investigate the way that this change influences residents' perceptions of the oil and natural gas industry. This section draws on our findings to explore the social context of emerging narratives and issues of trust and personal efficacy. We also discuss potential implications of our work for understanding how environmental shocks affect public narratives of change in other contexts.

##### **4.1 Constructing Social Energy Narratives**

Fundamental to our understanding of Oklahoma's post-seismicity narratives is a common assumption that we suggest is inherited from the prevailing social understanding of energy in Oklahoma prior to induced seismicity. That is, the oil and natural gas industry is important for Oklahoma and has provided benefits for generations. Nearly everyone who spoke with us made some reference to Oklahoma's oil and gas history, the many jobs associated with the industry, and the benefits this history has brought to the state. Many referenced family members who work in the industry; few noted a history of periodic painful bust cycles. We emphasize this assumption because it is not obvious that this perception would be shared as widely as it seems to be, particularly given the focus on the jobs and economic benefits of oil and gas as opposed to environment troubles, boom and bust histories, or other issues. This pre-seismicity assumption is retained across all three narratives outlined in Section 3, which all reflect the assumption that earthquakes are undesirable but oil and gas is currently important to Oklahoma's economy (though Narrative 2 perhaps challenges the idea that this should remain true).

A consequence of the shared assumption that earthquakes are undesirable but oil and gas are important to Oklahoma is that interviewees across our spectrum expressed similar beliefs about what the majority of Oklahomans think about seismicity. That is, most interviewees assume that the general population is concerned about earthquakes but wants to preserve the industry. In

many ways, this is not a mobilizing narrative (see e.g. [5]) and may in fact be limiting with respect to people's understanding of the social landscape. The challenge is that because this impression is rooted in a widely-shared societal assumption about public allegiance to the oil and gas industry, it is not clear that people's own reactions or understandings of others' reactions are based in a reflective examination of what they really think, rather than on a logical extension of a shared assumption. The reason that this potential lack of reflection is important is that if Oklahoma is to make serious decisions about its future that are based on public priorities, it is relevant that expressions of those public priorities might not be based on full multicriteria consideration of what people want for their communities. Rather, they are based on reactions to a specific type of event—earthquakes—that are heavily mediated by a positive societal impression of a single industry—oil and gas. That is, opinions are both reactive and anchored.

In our research, we observe some cognitive dissonance associated with the adoption of a social assumption rather than construction of personal assumptions. This dissonance is evidence in the way that interviewees differentiated public and private speech. In particular, notions of what makes acceptable public or private speech indicates that people are cautious about openly expressing their opinions. We observe such restraint among interviewees whose perspectives correspond with all three narratives we identify. Most strikingly, a Narrative 2 interviewee discusses his observation that people are reluctant to publicly acknowledge they have reservations about the oil industry:

We thought we knew people weren't going to want to talk because this is, we're going into small towns or reasonably small towns and we assumed, you know, "I don't want my neighbor to think I'm anti-oil," you know, it's a big thing. So we set up a website, completely anonymous. "Send us your stories, send us photos, you don't have to send us your name, we won't say who you are." To this day I've had very few. And when we met them personally in these meetings, town hall meetings were the best thing that I have ever been involved in and where they could look you in the eye and talk to you...I think they're just desperate for someone to feel that they are actually listening to them. Because some of the stories they had had just moved me to tears at very deep moments...they need someone to tell them and acknowledge face-to-face that they're not imagining. –"Dave," environmental organization

In this anecdote, residents questioning the overall narrative that oil is good for their communities are unwilling to share deeply important concerns without establishing a high level of trust and reciprocity. That is, stories are shared face-to-face with someone who initiates a conversation that challenges the assumption that the oil industry should not be criticized, but not otherwise. Another interviewee notes similar experiences in a small town, with neighbors who feel conflicted about balancing experienced harm and desire not to lose oil development:

I've got probably ten different people in town that said to me, yeah, my house is damaged, but they won't say it in public. And they won't ask for any help on it but they'll show me pictures. You know, but they're not joining any lawsuits and they're not going to, you know, they don't want the media to come. –"Jennifer," affected resident

This hesitation to openly criticize the oil and gas industry is also suggested by the fact that we did not hear strong support for ending extraction activity or switching to renewable energy, in contrast with observations in regions experiencing mountaintop removal coal mining (MTR) [27] or new shale gas development [28]. Even the group of people who see seismicity as a major and unacceptable issue focus attention on regulators and government actors or on the possibility of personal actions like moving. Calls to shut down oil and gas industry activity are largely focused on high volume injection wells or hydraulic fracturing, not the entire industry. This observation is consistent with literature indicating that induced seismicity is more acceptable when it is associated with a public or personal benefit (e.g. [18, 29]). However, particularly given our effort to identify individuals and groups perceived as very engaged environmentalists, we expected to find a more radically anti-industry narrative.

Just as people are hesitant to openly question the assumption that oil and gas activity is positive for Oklahoma, others are hesitant to suggest that the earthquakes are an acceptable outcome. When pressed on whether they thought Oklahoma could live with earthquakes, several people responded noncommittally and reiterated that even though they personally did not find the earthquakes to be overly concerning, the earthquakes are certainly a big problem for the state. One explicitly references a public/private speech distinction:

I'm not going to say, you know, these aren't big earthquakes and, very insensitive thing to say in a way, but having lived through one of the Moore tornadoes that just decimated the city...forty some odd people were killed and a whole swath through a medium-sized city was destroyed. And you know so these earthquakes compared to the severe weather in Oklahoma are pretty minor concerns. [laughs] And I started laughing there, but it's just one kind of thing you would never...you'd be killed if you said something about that in a public discussion about the earthquake hazards or the earthquake activity. –Henry, academic

We suggest that our findings in Oklahoma demonstrate the power of shared social narratives that are likely also present in other policy-relevant contexts (see e.g. [10, 15]). Cultural understanding of different energy resources can be conspicuous and persistent ([30], this issue), and politicization of topics like climate change can have far-reaching implications that have little to do with people's fully considered priorities (for more on the role of values and climate change, see e.g. [31]). Given the power of narratives to shape public response, considering the context of shared social assumptions can enhance understanding of the narratives that emerge in response to a stimulus, like induced seismicity in Oklahoma.

#### **4.2 Narratives, Group Identity, and Personal Efficacy**

Shared social assumptions help shape narratives, and we suggest that individuals' identification with relevant social networks helps drive motivation to engage in activities based on those narratives. For this study, we observe strong correlations between narratives and group identities like industry affiliation or activist communities. Groups and narratives are likely co-constructed (see e.g. [32] for more on the relationship between social networks and narrative). In some cases,

a pre-existing group identity appears to influence an individual's assumptions, which in turn align with a narrative. For example, some members of industry, government, or environmental organizations already have assumptions about the ability of the oil and gas industry to operate cleanly and safely or not. In other cases, an individual's personal assumptions lead to group formation and, in turn, affiliation with a new community. For example, residents who perceive damage to their homes that is far greater than what the news reports suggest is happening might seek one another and form activist communities. We posit that group identity is closely related to people's sense of personal efficacy, or sense that they can achieve their goals, which in turn is related to their sense of well-being. Uncertainty is widely associated with stress and fear [33], so we expect that a shared understanding of what is happening and what should therefore be done is helpful in reducing such stress and fear in the context of induced seismicity, which in turn may be more likely to create action.

Our research and that of others (e.g. [34]) suggest that it is widely understood that seismicity is related to the oil and natural gas industry. This consensus is important for several reasons: first, because it focuses narratives about what should be done; second, because it implicates an economically important and familiar industry in the creation of a problem that is widely disliked; and third, because it reparameterizes uncertainty in the context of seismicity. Specifically, while early earthquakes were characterized by uncertainty about both the causes and the potential effects, current uncertainty focuses on effects.

We anticipate that understanding the cause of induced seismicity likely increases some residents' sense of personal efficacy because it increases the extent to which they feel they take action in the context of a social support network. Interviewees expressing experiences consistent with Narrative 1 ("Lesson learned, let's move on") or Narrative 2 ("Earthquakes must not continue") more frequently articulated actions they have taken or could take. Further, these interviewees more frequently discussed positive experiences of group membership related to induced seismicity. In Narrative 1, this takes the form of industry-government collaborations to learn about and react to induced seismicity. In Narrative 2, this takes the form of involvement in discussion fora both in-person and online, protests, attendance at community meetings, and other events where they are not alone in their concern. The main difference between the least concerned (Narrative 1) and most concerned (Narrative 2) communities is that Narrative 1 members feel a strong sense of control over the ultimate outcome, while Narrative 2 members do not. In our small sample, this difference is likely due in part to the higher incidence of Narrative 1 among industry affiliates who have actual decision making power about policy, injection volumes, and other issues, and, by contrast, to the higher incidence of Narrative 2 among activists and residents who self-identify as holding minority views.

It is Narrative 3 ("There's a solution, right?")—characterized by uncertainty about whether earthquakes or continued economic contributions by the oil and gas industry are more important—that is least associated with community formation and a clear course of action. Action and discussion tend to anchor on specific seismic events, but engagement fades quickly. Unlike those expressing Narratives 1 and 2, primarily concerned about economic sustainability and environmental sustainability, respectively, Narrative 3 members are concerned about both.

This group does not have a sustained call to action that extends beyond experience of seismic events, other than to be concerned about both earthquakes and the potential loss of oil and gas industry benefits. We thus posit that subscribing to Narrative 3 creates the most stress for individuals, as this tension does not foster either community formation or personal action. That is, social support and personal efficacy are both limited. While understanding the link between seismicity and oil and gas increases clarity on a course of action under Narratives 1 and 2—e.g., “make regulatory and operational decisions to protect the enterprise” or “protest a harmful industry,”—it might actually decrease clarity in the context of Narrative 3. Without the causal link between seismicity and oil and gas, earthquakes are completely outside one’s control. When the earthquakes are human-caused, a very difficult choice (under Narrative 3 assumptions) must be made: namely, sacrifice economic benefits and jobs associated with a familiar and important industry, or else accept the earthquakes. In this narrative, introducing the concept that earthquakes are anthropogenic actually reduces informants’ sense of personal efficacy because they neither believe that the problem will be solved without much impact to industry (as with Narrative 1) nor that the problem is severe enough to warrant opposition to industry (as with Narrative 2). One college student studying chemical engineering notes:

I would go to career fairs and there would be these oil companies and they would just be sitting there telling me about fracking and I would just be silently disapproving...I was thinking at that point that these could be my future employers so I’m just not going to say anything. —“Samantha,” student

“Samantha” also expressed fear and a sense that nothing was likely to be done to change the situation. A frequent theme of Narrative 3 comments is that earthquakes are a source of stress, but interviewees do not feel like much can be done. Some interviewees noted taking action to protect themselves by purchasing earthquake insurance, but most quickly followed up by noting that such insurance is expensive and uncertain, particularly given the fact that deductibles are generally very high. This action is made alone, however, without the support of shared experience in a group.

#### **4.3 Institutional Trust**

In considering the relationship between group membership and activity in the induced seismicity context, we observed high levels of trust among group members via bonding ties (see [32]), manifested in the way that interviewees spoke of facts they believed or future developments they expected to see. For interviewees from industry, government, and environmental activist communities, this trust extended to specific members of groups usually seen as unbiased—but not others—based on prior history with those individuals. Most notably, each group of interviewees referenced specific journalists and scientists by name, with high overlap within the groups and no overlap between groups (see [6] for an example of this phenomenon from a researcher’s perspective). The Narrative 3 interviewees, who did not articulate belonging to seismicity-related groups, did not reference journalists and scientists and often were unsure of which information they trusted. Based on this observation, we investigated the way that trust in other groups or institutions was referenced by our interviewees.

Loss or lack of trust in government was more explicitly observed than loss or lack of trust in industry, at least among our interviewees. This observation is consistent with the concept of recreancy, or perception of failure associated with institutions expected to protect the public [35]. Many of our interviewees brought up the governor's Coordinating Council on Seismic Activity. "Rick" (industry/government) called it a "really successful venture," but this was a relatively unusual reaction outside Narrative 1. Others referenced it somewhat disparagingly, with one person referring to it as "Mary Fallin's super secret committee on earthquakes" ("Jennifer," affected resident). Another interviewee characterized the reaction to the recent large seismic event as "lots of politics, less protests...Less so directed at the industry. I feel like a lot more of it was directed at the governor" ("Melissa," academic). Beyond discussion of the governor's initiative in particular, multiple interviewees noted they felt that the relationship between the Oklahoma Corporation Commission (OCC, the oil and gas industry's main regulator in Oklahoma) and industry was not straightforward. Industry affiliates tended to see the OCC as relatively ineffective compared to companies, while environmental group affiliates tended to see the companies as resistant to OCC directives. An interesting contrast in perspective comes from "Bob", as part of a conversation indicating that OCC directives were largely determined by what companies presented to the OCC as appropriate:

The OCC was constructive to work with. And ultimately easy to work with, again, partially because they had no capability. –"Bob," industry

contrasted with "Dave's" (environmental organization) take:

This was all driven by the Oklahoma Corporation Commission. Not a single oil and gas company said "Damn, look what we're doing, what can we do to fix that?" –"Dave," environmental organization

Overall, based on our work, trust in the regulators in Oklahoma appears to be relatively low. While industry was brought up frequently in the abstract, notably, references to specific companies or specific projects were effectively nonexistent. Industry was frequently referenced as a proxy for the economy (e.g. "I know oil and gas are important") rather than as a group of actors. When asked directly whether seismicity caused them to trust industry less, some interviewees responded affirmatively, but tentatively:

[laughs] A little bit, yes. I wouldn't say I distrust industry, but this was not the best way it could have been handled. –"Susan," affected resident

The greater focus on regulator and government action versus calls for industry to act is potentially explained by shared social assumption that seismicity is a problem, but oil and gas is important to Oklahoma. The combination of negatively perceived earthquakes and positively perceived economic outcomes of oil and gas development suggests that Oklahoma residents are looking for a way to balance competing priorities and interests, a role that traditionally falls to regulators. In a setting where historical conditions have had oil and gas acting in ways that

benefit the state, with primary responsibility for limiting and guiding this development falling to the regulator, a more explicit loss of trust in the regulator versus the industry itself makes sense.

#### **4.4 Narratives of Energy Hazards and Public Communication**

Induced seismicity in Oklahoma and the public response to its emergence represents an opportunity to understand how a negative event changes the way that people think about and act upon environmental issues. Climate change is often perceived as a challenging issue to communicate and make salient because of its widespread and slow (on human time scales) effects, many of which are not clearly linked to a human action that can be acted upon (see e.g. [36]). Suggestions that environmental disasters like 2010's BP Oil Spill can be used to harness public attention to make change have been challenged by observations indicating that it is difficult to capture attention on the time scale necessary to make policy (see e.g. [37]). Further, many "disasters" of this nature are isolated events linked to poor processes and procedures, i.e. accidents that are at least theoretically preventable. Induced seismicity, by contrast, is a fast-emerging issue that is clearly tied to a specific activity that was performed for decades before causing problems: that is, the hazard is salient and linked to a core activity of oil and natural gas development in Oklahoma.

Induced seismicity occupies an intermediate position between single event disasters like BP's Macondo blowout and slow disasters like climate change. Despite its blend of salience-prompting individual seismic events and long-term relevance associated with possibly cumulative risk due to pressure build up, our research suggests that induced seismicity has become fairly normalized. As activist "Tammy" notes of her group:

Much fewer people were showing up...because they stopped feeling like it was a problem, or I think they started feeling like it's still a problem but there's nothing they can do about it. —"Tammy," environmental organization

Recall also that "Bob" (industry) was surprised by the lack of media attention after the Pawnee earthquake, despite previous high intensity engagement (Section 3.4). This decrease in sustained attention even in focused organizations, with social support and a clear goal, suggests that challenges associated with sustaining public attention that have been observed in the aftermath of single event or slow disasters (see e.g. [38]) is also present for a long-term problem punctuated by many single events, like induced seismicity. Creating policy frameworks to address public priorities likely cannot rely on sustained public interest alone. Instead, resonant frames (see e.g. [39]) and emphasis on understanding people's value orientations [31] are likely to be important.

#### **5 Conclusions**

Our research on post-seismicity narratives about oil and gas in Oklahoma suggests that a sudden shift in outcomes caused by even a familiar industry activity affects the way that people perceive the energy landscape. In particular, we identify three major narratives with somewhat different political implications: one framing seismicity as a problem that can be resolved without harm to the oil and gas industry; one framing seismicity as one of several unacceptable risks whose resolution requires active changes in oil and gas; one framing seismicity as a problem in tension

with public interest in preserving the economic and social benefits of oil and gas, but without a clear course of action. The three narratives we identify share a pre-seismicity assumption that oil and gas are good for Oklahoma, an assumption we suggest has a major influence on public discussion of induced seismicity. Our work also suggests that new narratives are strengthened by the existence of associated group identity that allows for people to feel effective within a collective effort alongside people they come to trust. Further, despite a shared understanding that seismicity is likely induced by wastewater injection associated with oil and gas development, we observe more explicit distrust of regulatory reaction than of industry. While we acknowledge the limitations of our relatively small study, this Oklahoma seismicity case study adds to work on social response to single, isolated events or long-term, slow disasters, suggesting that understanding shared social assumptions, group formation, and the importance of trust can contextualize the rapid normalization of even highly undesirable outcomes like earthquakes. Residents agree that seismicity is undesirable; how that undesirable outcome is ultimately addressed remains to be seen.

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## 7 Disclosure Statement

EG performed paid consulting work related to technical aspects of wastewater disposal for an Oklahoma-based oil company in 2014-2015, engaged in concurrent unpaid research on decision making in industry, and has a relative currently employed by an Oklahoma-based oil company. No direct financial relationship with the company has existed or been anticipated since April 2015, over a year before this research was proposed and designed. Both authors have relatives in Oklahoma who have experienced induced seismicity.

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