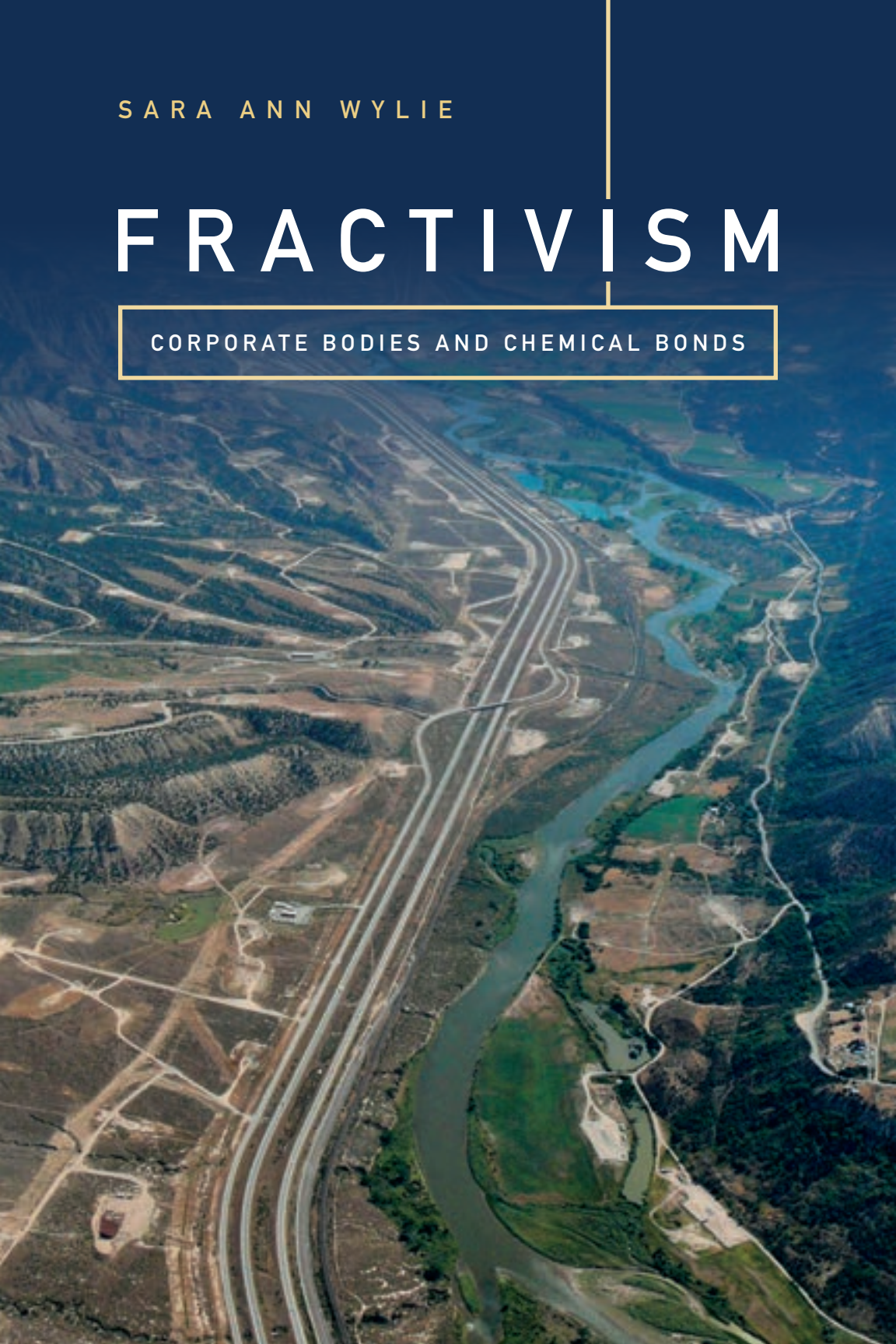
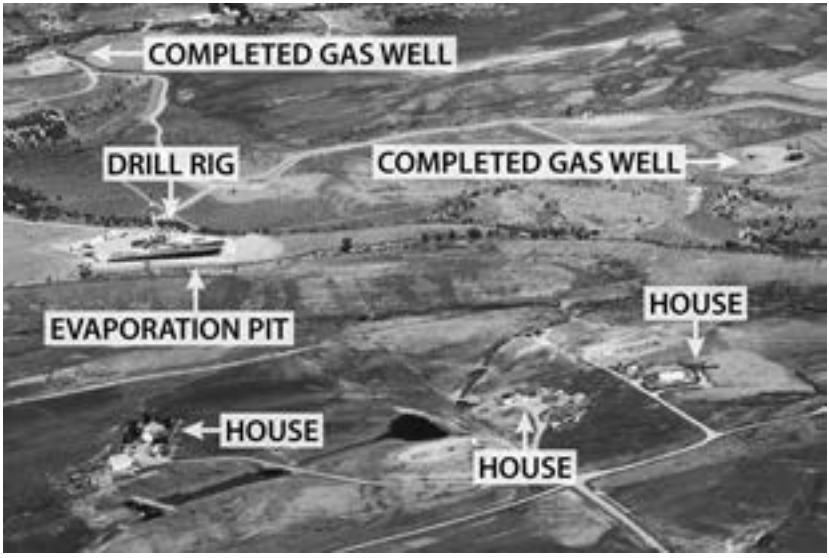
SARA ANN WYLIE

FRACTIVISM

CORPORATE BODIES AND CHEMICAL BONDS



FRACTIVISM



Oil and gas wells next to homes in Colorado, 2006.

Experimental Futures

TECHNOLOGICAL LIVES, SCIENTIFIC ARTS, ANTHROPOLOGICAL VOICES
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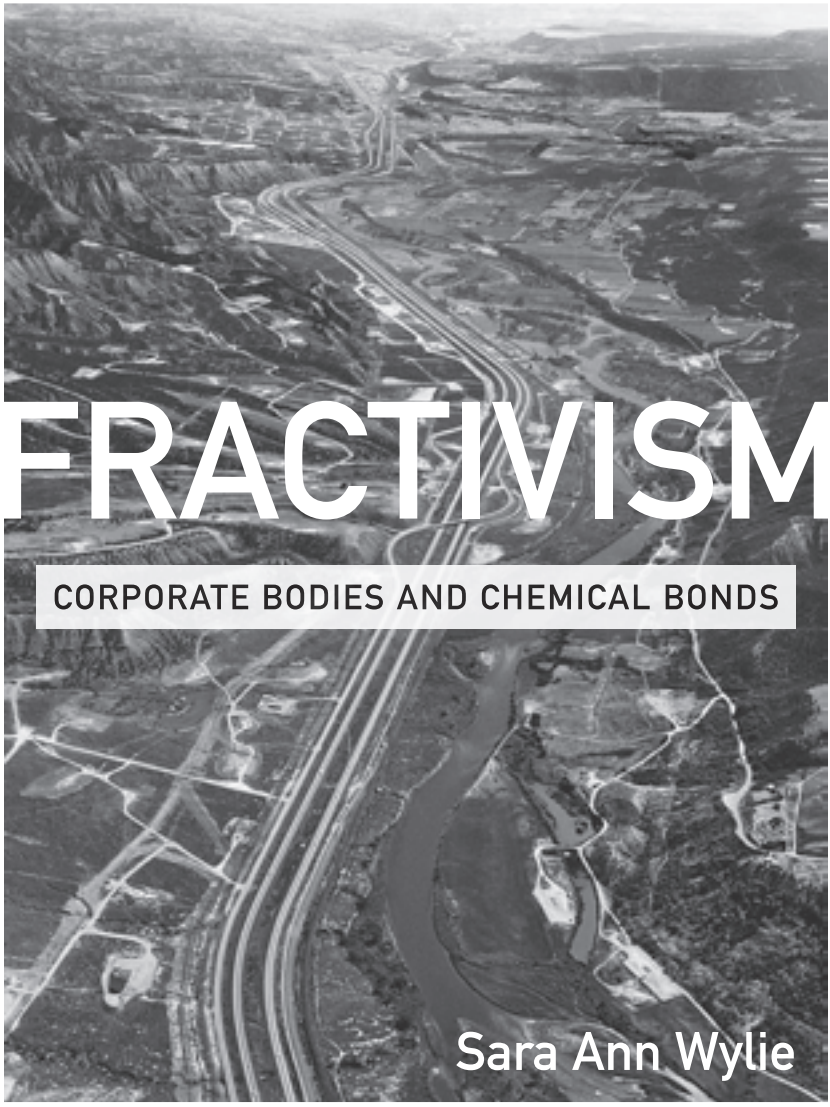

Oil and gas development along the Colorado River and I-70 in 2006.

Duke University Press

DURHAM AND LONDON 2018

Printed in the United States of America on acid-free paper ∞
Designed by Matt Tauch
Typeset in Minion by Westchester Publishing Services

Library of Congress Cataloging-in-Publication Data
Names: Wylie, Sara Ann, [date—] author.
Title: Fractivism : corporate bodies and chemical bonds / Sara Wylie.
Description: Durham : Duke University Press, 2018. | Series: Experimental futures | Other title, changed in ECIP : "Shale Gas" | Includes bibliographical references and index.
Identifiers: LCCN 2017036329 (print) | LCCN 2017056103 (ebook)
ISBN 9780822372981 (ebook)
ISBN 9780822363828 (hardcover : alk. paper)
ISBN 9780822369028 (pbk. : alk. paper)
Subjects: LCSH: Hydraulic fracturing—Health aspects. | Hydraulic fracturing—Environmental aspects.
Classification: LCC TN871.255 (ebook) | LCC TN871.255 .W955 2018 (print) | DDC 338.2/7283—dc23
LC record available at https://lccn.loc.gov/2017036329

Cover art: Oil and gas development along the Colorado River and I-70 in 2006. Photo courtesy of TEDX.

Fractivism is a neologism combining "fracking" and "activism."

As WellWatch and Landman Report Card are no longer online, materials from these websites can be found on Sara Wylie's website: https://sarawylie.com/publications/fractivism-corporate-bodies-and-chemical-bonds/.

This book is dedicated to those who made it possible:

THEO COLBORN—never have I encountered a more powerful personality, a being so bent on transforming the world around herself. She was a mentor and an inspiration. I feel honored to have known her. I hope this book does justice to her work and spirit.

DR. JOAN RUDERMAN—without the hours spent in her lab, without the grudging trip I took to the library to dig up *Our Stolen Future*, without our conversations muddling through endocrine disruption and assays, this project would never have begun.

CHRIS CSIKSZENTMIHÁLYI—without Chris's invitation to collaborate on ExtrAct, I would not have made the move to "making" as well as writing critique. He fundamentally changed my approach to scholarship; he gave me the concrete tools, confidence, and opportunity to begin putting STS into practice.

This project has been years in the making; I had my first interview with Theo in 2005. Along the way, countless people have played pivotal roles in shaping its and my own evolution. My hope is that the book itself does justice to their contributions because I can't write them all out here without writing a second book. This work is dedicated to all of them, to the community organizers, landowners, academics, artists, scientists, engineers, programmers, friends, and family who daily work in micro and macro ways to build more equitable, just, and responsible futures. May this work contribute one more ripple toward changing how we collectively inhabit this amazing world.

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PREFACE

Unconventional oil and natural gas extraction in the early twenty-first century has transformed social, physical, economic, legal, and biological landscapes in the United States. From 2000 to 2014, shale gas production increased from near zero to approximately 40 billion cubic feet per day, making the United States the world's largest natural gas and oil producer (Smith 2014; EIA 2015). The dramatic growth of U.S. oil and gas prices produced record low prices for oil and gas in 2015, leading to declines in production, job losses, and bankruptcies (Frazier 2016; Hunn 2016; Scheyder 2016). Hydraulic fracturing (fracking) that entails high-pressure injection of synthetic chemical mixtures into subsurface formations made drawing oil and natural gas from previously unreachable reserves possible. Thirty-two states now produce unconventional fossil fuels (EIA 2013b) at an unprecedented scale (EIA 2013a). Extraction from the Brakken Shale in North Dakota produced new human settlements visible from space (J. Amos 2012; Swanson 2014).

Industry and regulators promote unconventional gas and oil production as the key to U.S. energy independence and as a bridge to a low-carbon economy (MITEI 2011; Graves 2012; G. Zuckerman 2013). But there is another side to the story. In 2014, New York State became the first state rich in unconventional natural gas to ban fracking due to human health and environmental concerns (Lustgarten 2014). Debates over fracking are being fought state by state everywhere that the practice spreads; the 8,696 unconventional shale wells drilled in Pennsylvania from 2000 to 2014 incurred 5,983 violations from the Department of Environmental Protection (Kelso 2014). Earthquakes in Alabama, Ohio, Oklahoma, and Texas are linked to the injection of fracking wastewater—3.5 billion barrels in Texas alone in 2011 (up from 46 million in 2005) (Hargrove 2014). Research in Pennsylvania, Texas, and

Colorado shows fracking-contaminated ground and surface water is destroying the lives and livelihoods of landowners (Jackson et al. 2013; Warner et al. 2013; Darrah et al. 2014; Kassotis et al. 2014). Furthermore, natural gas may be no more "green" than coal. Life-cycle analyses of its production reveal that tons of methane are released into the atmosphere when natural gas is processed and transported (Howarth, Santoro, and Ingraffea 2011; Karion et al. 2013; S. Miller et al. 2013; Pétron et al. 2014). Methane is a far more potent greenhouse gas than carbon dioxide (Myhre et al. 2013).

This book explores the emergence of both the gas boom and its controversies, offering innovative scientific approaches to studying gas extraction's harmful impacts on human health and the environment. Via participant observation within a small scientific advocacy organization, The Endocrine Disruption Exchange (TEDX), I follow the development of the first database of chemicals used in natural gas extraction, a database that documents not only the (often proprietary) constituents of fracking chemicals but also their bodily and ecological effects. My ethnographic analyses of TEDX's database demonstrate how it transformed an information vacuum around fracturing into fierce regional and national debates about the public health effects of this activity.

Expanding on TEDX's databasing methodology, the book describes the research, development, and impacts of a set of online, user-generated databasing and mapping tools designed to interconnect communities encountering the corporate forces and chemical processes animating gas development. Fracking is an intensive, technological practice that requires the delicate calibration of corporate, governmental, and legal apparatuses in order to proceed. The industry operates at county, state, federal, and international levels, and it has successfully organized regulatory environments suited to rapid and lucrative gas extraction. Amid such multiscalar forces, communities have little legal or technical recourse if they have been subjected to chemical and corporate influences that undermine their financial, bodily, and social security. ExtrAct, a research group I cofounded and directed with the artist and technologist Chris Csikszentmihályi, sought to empower isolated local communities by developing a suite of online mapping and databasing tools through which gas-patch communities exposed to fracking could share information, network, study, and respond to industry activity across states. Using ExtrAct as an example, I explore how social sciences and the academy at large can invest in developing research tools, methods, and programs designed for noncorporate ends to help redress the informational and technical imbalances faced by communities dealing with large-scale multinational industries.

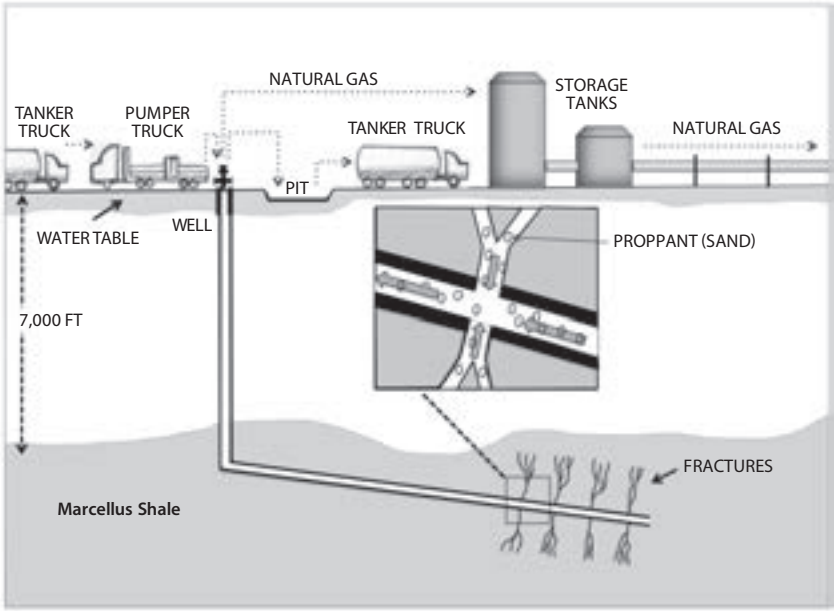

FIGURE P.1. The process of hydraulic fracking.

In unconventional gas reserves, gas is distributed throughout a porous matrix like coal or sandstone. Fracking creates a route through which this gas can be brought to the surface (EPA 2004) by injecting a mixture of synthetic chemicals under extremely high pressure into the porous matrix. A high-volume hydraulic frack is a large-scale industrial operation. A cavalcade of 18-wheeler trucks bearing containers filled with the thousands of gallons of fluid and associated machinery necessary for the procedure draws up to a frack site (see figure P.1). These containers are arranged around the "head" of the well to be fracked and then connect to the wellhead to form what looks like an octopus of piping.

Within the containers, blending machinery mixes fracturing fluids composed of dry or nondiluted stores of chemicals and other materials such as proppants, sand, or other grainy materials used to prop the fractures open (Montgomery and Smith 2010: 30).[1] This mixture is forced into the well by powerful diesel engines capable of producing 15,000 hhp (hydraulic horsepower), which is roughly equivalent to about twenty-three 650 hp 18-wheel truck engines roaring to life as a frack operation begins (Montgomery and Smith 2010: 30). A frack operation can continue for many hours as the mixture is pumped underground at a high-enough pressure to break pathways

in the subsurface gas-bearing layer thousands of meters below the surface. The force of these fluids generates a mini-seismic event. A single frack can require one million gallons of fluid, and a well might be fracked from three to 40 times during its life cycle. On average, each horizontally drilled well in the United States undergoes 10 fracking cycles (Montgomery and Smith 2010: 27, 28, 35). Most horizontally drilled wells in the Marcellus Shale region, the largest natural gas-producing region in the United States in 2013, extend two kilometers below the surface and over a kilometer into shale beds (Kemp 2014).

The combination of horizontal drilling and fracking has transformed oil and gas resource extraction. Rather than sinking individual wells into pockets of gas or oil, the oil and gas industry can now collect fossil-fuel resources from across a formation, drawing gas and oil from kilometers of pipe drilled laterally through a shale bed.

ACKNOWLEDGMENTS

Now to the practical and less poetic acknowl edgments: First, I sincerely thank the academics who inspired this proj ect methodologically, theoretically, and materially; chief among them are (in alphabetical order) Joseph Dumit, Mike Fischer, Kim Fortun, Stefan Helmreich, Susan Silbey, and Chris Walley. At each stage of this work, I was also fortunate to work with research groups whose conversation and collaborations inspired the proj ect's development:

- BioGroup at MIT: Sophia Roosth, Natasha Myers, and Etienne Benson, with leadership from Stefan Helmreich. We delved into questions of sensing and making sense that permeate this whole narrative.
- ExtrAct: Of course, this group is central to this project. The ExtrAct Team, particularly Chris Csikszentmihályi, Dan Ring, Christina Xu, Matt Hockenberry, Lisa Sumi, Jennifer Goldman, and Tara Meixsell, as well as our great research assistants and interns—I know I don't do justice to your characters and efforts here; would that there could be more volumes. Also thanks to the rest of the Computing Culture group for your inspirational work performing critique, and thanks to the larger community of the Center for Future Civic Media for not just asking but trying to answer the question of how to build infrastruc-tures for informed communities and democratic accountability.
- The Rhode Island School of Design (RISD) Environmental Justice Research Cluster: Special thanks to Kelly Dobson for creating the opportunity for me to teach at RISD and lead a research group as well as inspiring me with her thought-provoking work and lasting friendship. Also to Jeff Warren who co-led the group and Megan

McLaughlin who worked tirelessly on the hydrogen sulfide monitoring project.

- Public Lab: Nothing makes me prouder than my part in cofounding Public Lab, an online community for developing open-source hardware and software for community-based environmental monitoring. Many of the ideas behind Public Lab animate the ending of this book; thanks to fellow cofounders Liz Barry, Shannon Dosemagen, Adam Griffith, Stewart Long, Matt Lippincott, and Jeff Warren. It is amazing to see this seed bearing fruit.
- The Social Science Environmental Health Research Institute (SSEHRI) at Northeastern University: SSEHRI has been a welcome academic home, allowing for drafts of multiple chapters to be reviewed. I'd particularly like to thank Phil Brown for welcoming me to SSEHRI. Special thanks also to Len Albright, who coauthored chapter 10 of this book, and to the other members of our hydraulic fracturing research group, particularly Elisabeth Wilder, Jacob Matz, and Lauren Richter. Deep thanks to Lourdes Vera for her amazing support in figuring out the book's figures and her fantastic research work on the hydrogen sulfide monitoring project.

Beyond participating in these research collectives, contributing to three edited volumes helped connect me and this book to the larger scholarly efforts in social sciences to comprehend, track, and reform unconventional energy extraction and to develop engaged forms of scholarship. I thank all of the authors and editors of *Subterranean Estates: Life Worlds of Oil and Gas*, particularly Michael Watts, Hannah Appel, and Susanna Sawyer whose work shaped this book. Working with Matt Ratto and Kirk Jalbert on the special issue of *Information Society* about critical making helped develop my thinking on civic technoscience. Finally, coediting a special issue of *Journal of Political Ecology* on hydraulic fracking with Anna Willow brought together a powerful group of anthropologists who are still actively connected through the Society of Applied Anthropology's extraction working group.

Adding to this wealth of scholarly support and inspiration are my collaborators in making and doing STS, namely, Max Liboiron, Nick Shapiro, and Dvera Saxton, who advised on the final chapters of this book.

I am deeply grateful to be part of such a thriving community of academics and part of an era in history where cultural critique is valued, so that research such as this is funded. The work described here has been made possible with funding from the National Science Foundation IGERT graduate

research training program, the Knight Foundation's News Challenge, the American Anthropological Association Environmental Section's small grants program, numerous public contributions to Public Lab through Kickstarter.org, Northeastern University's College of Social Sciences and Humanities, and the JPB Foundation's Environmental Health Fellowship program, organized through the Harvard School of Public Health. It is my fervent hope that we can together prove the social, ethical, and scientific worth of increasing our collective investment in making cultural critique vital to education, policy, and industry.

Connected to, mixed with, and yet still distinct from these academics are the remarkable community members and nonprofit organizations that collaborated on many parts of this story. First, The Endocrine Disruption Exchange (TEDX), founded by Theo Colborn to continue her database of research on endocrine disruption and carried on by Carol Kwiatkowski. TEDX is a unique and vital organization to the larger movement of endocrine disruption research and reform. My thanks goes to the entire staff, particularly Lynn, Mary, and Kim.

Through TEDX, I had the great pleasure of coming to collaborate with Earthworks/Oil and Gas Accountability Project (OGAP) on ExtrAct. Particular thanks to Lisa Sumi and Jennifer Goldman who were essential parts of the ExtrAct team and to Bruce Baizel, Gwen Lachelt, and Sharon Wilson who supported this and our current collaborative projects.

OGAP led ExtrAct to work with many remarkable landowners and citizens' organizations from San Juan Citizens Alliance to North East Ohio Gas Accountability Project. I'll forever remember traveling the gas patch with Rick Roles, whose story begins and ends this book, as well as time spent with Sug and Jack in New Mexico and Calvin Tillman and Sharon Wilson in Texas, as well as hearing the stories of Deb Thomas, Kari Matsko, Mark and Carol, Dee, and the Fitzgeralds. The measure of success in reforming this industry must be material improvement in the lives of those it negatively impacts. Let's hope that working together we can meet that mark.

Then there are the editors. It was no small task to reduce a manuscript from 700 pages to its finely honed present-day form. Luckily I benefited from great support in the effort. Many, many thanks to Julia Ravell for editing and fact-checking the entire work. I also had the great fortune to work with Dr. Jo-Linda Butterfield, whose practical advice on time management and thought untangling not only created beautiful post-it art all over my walls but also literally helped order my thoughts into the linear format that the written word demands. This linear, sequential format is utterly insufficient to the task

of thanking my mother for the hours she spent working through drafts of each and every chapter with me. There are too few women out there benefiting from having an academic mum, who has already charted the academy's rough terrain. I could not hope for a better field guide and more constant companion than Janet (Heasman) Wylie. A sea of cross-current thoughts and emotions could not express my gratitude.

Which brings me to the heart of the matter: the friends and family who reminded me that not all life is work and that the deepest joy is in the smallest moments of intersection during our chaotic, unique, and fleeting courses through this material world. Friends, Father, Brothers, Sisters, Husband, Son, you make life worth living and a lot of fun.

INTRODUCTION

An STS Analysis of Natural Gas Development in the United States

An Ethnographic Tour of the Gas Patch

I was talking to one of the neighbors night before last, at the last forum. They were asking about the condensate [a term for fluid produced during natural gas and oil development], and he [a representative from a gas company] said, "Ah, it's just water, nothing to worry about." Oh, I told him, I wish I'd have been there! I'd go and get me a quart jar and carry it around in the truck from now on, of condensate,[1] and when he says that, I'm going to break his jaw, and then make him drink it. Then I'll tell him, "Can you still use your cell phone? Because you'd better get a paramedic over here quick. It ain't going to do much good though, because they don't know what the chemicals are over at the hospitals or nothing. They can't treat you."—RICK ROLES (summer 2006)

Rick Roles has 19 natural gas wells on his property. It was a sweltering August morning in 2006 when the rancher and landowner from the western slope of Colorado told me the story above.[2] He had just arrived in his beaten-up, faded blue pickup truck, fuming. Rick's eyes were partially shaded by his weatherworn white cowboy hat, and his tangle of long hair was in a ponytail. He was tired, and angry, but ready to talk, ready to give a tour of life in the Garfield County gas patch. "Gas patch" is a term used by residents and the oil and gas industry to describe an area devoted to drilling for natural gas

reserves. Roles, like many others, was becoming convinced that fluids produced during gas extraction were extremely dangerous.

Theo Colborn, one of the world's most prominent environmental health scientists;[3] Lisa Sumi, a veteran activist; and I, then a graduate student from MIT studying Theo's research process as part of my PhD in anthropology of science, listened to Rick under a corrugated iron shelter that gave some respite from the heat. The shelter was intended for picnickers who might stop for a rest from Interstate 1-70, just outside the small rural ranching community of Rifle, Colorado. It was less than scenic: a bit of asphalt and scrub stuck between the Colorado River and 1-70, but it counted as a town park, and people went there to fish and picnic, "not too far from the sewage treatment ponds," as Theo observed. With our spread of fresh and homemade food on the table, we probably looked like picnickers. Theo felt it important to feed Rick up. His body had become temperamental and ill since gas drilling had begun on his ranch.

The story of natural gas drilling brought us together. Lisa Sumi, of Japanese descent, self-described as "little, yellow, different," grew up in Wawa, Canada, a small mining town on the Great Lakes.[4] Her mining town's story, where no one wanted to talk about arsenic pollution, drew her into studying the health hazards of extractive industries. She was then the research director of a small advocacy organization—the Oil and Gas Accountability Project (OGAP)—based in another small town, Durango, in another large gas patch, the San Juan Basin.[5] She had come to catch up on the database that Theo was amassing of potentially hazardous chemicals used in gas development. But mainly she was here to tour the Rifle gas patch and to meet Rick Roles.

Theo had organized the tour as well as the food. The fried chicken she had prepared sat thawing in the sun in Tupperware containers. She had frozen it to keep it fresh during the drive over the Grand Mesa—a great table, indeed, America's largest flat-topped mountain. Now she was worrying that it was too frozen. It was. Luckily we had peaches, fresh from the local organic farmstand on the road leading out of Paonia, the town where Theo lived and worked. Eating organic foods had become important to Theo after she helped found the field of endocrine disruption. Endocrine disruption refers to chemicals that can interfere with hormonal signaling in the body, particularly during fetal development, and thereby disturb reproductive, neurological, and immunological functions (Colborn, Dumanoski, and Myers 1997; Krimsky 2000). Many pesticides have been recognized as endocrine disruptors (Colborn et al. 1997). Colborn's master's and PhD research showed how low levels of toxic chemicals in high-altitude streams in Colorado had

induced lasting biological effects (Colborn et al. 1997). During the 1990s she helped transform public, regulatory, and scientific evaluation of synthetic chemicals. This book describes how, between 2004 and 2011, Colborn and her research organization, The Endocrine Disruption Exchange (TEDX), based in Paonia, Colorado, raised national awareness about the public health problems associated with natural gas extraction. Paonia, a coal-mining and ranching community, is in a valley perfect for growing peaches and cherries. In the shadow of high mountains, its altitude and the mixture of snowmelt and agricultural runoff moderate Colorado's baking summer heat. It is an intriguing combination of sagebrush aridity, fruit trees, and coal mines.

Fresh fruit and home-cooked food, that is what Rick's body needed, according to Theo. He lives in a changing biological and physical landscape. He also carries it with him as he later explained, showing me the results of his blood work, revealing trace levels of benzene, toluene, ethylbenzene, and xylene (BTEX) in his body, in his blood.

Rick was the reason for our visit. We had come to hear how his body and his physical landscape had been changed by natural gas development. He told us about a school meeting, where concerned parents and faculty had gathered to learn more about a gas well that was to be located within a few hundred feet of the school grounds. "What about the toxic chemicals they are going to use?" someone had asked. "Toxic chemicals?" the company representative replied. "There are no toxic chemicals, just guar gum, sand, and water. That's it." "That's it!?" An outraged Rick reported, "They just lied to them."

Rick no longer believes what is said by gas industry reps. He lost faith when his property's value plummeted after the 19th well went in on his ranch and when his goats developed growths on their necks and gave birth to sacs of water. But he became really angry when his body stopped listening to him, when his limbs went numb randomly in the mornings and his hands cramped, so that he could not eat his breakfast because he could no longer pick up a spoon; when painkillers failed to assuage the wandering pains that traveled through his body and his mind slowed down, so that he could not remember things. A case of "classical chemical sensitivity," according to Theo. "Poisoning," says his holistic healer. Rick has a piece of paper, the evidence on his dashboard that he is not crazy, that there is something else in his body and in his land. Is this evidence enough, and who will listen?

After hearing Rick's stories, I joined Rick in his truck, so I could ask him questions, while Lisa and Theo followed behind on the dusty backroads of Rifle, a small town that does not really invite you to stop over. Most tourists, including myself before fieldwork brought me here, zip past on I-70, admiring

the steep valleys of banded ochre yellows, blushing reds, and clinging sage green, experiencing the cinematic recall of old Westerns—except for the rigs beside roads and heavy truck traffic. The road follows the Colorado River, through the wide valley it has cut between the Grand Mesa and the Roan Plateau, of which both are preserved wild lands protected as national forest and also heavily contested sites for natural gas development. Drill rigs flank us to the left and right of the road, up hills, in valleys, on mesas, by the river. In addition to the rigs there is a network of supporting infrastructure; a maze of unsigned, rutted roads, with 18-wheelers kicking up dusty clouds; large cylindrical condensate tanks; and supply yards and migratory labor camps. A lattice of pipelines and pressurizing compressor stations keeps the gas moving. Harder to detect from the ground are the waste pits, where fluids produced from drilling and fracking are stored. They are difficult to see from a car because they are flat. You can find them by looking from above, or, as Rick pointed out, by looking for changes in the soil around berms: ridges of built-up earth around the ground on which a well or pit stands. You can spot them because they make unusually even lines on the horizon. Rick had been tracking the use of a particular chemical called Soli-Bond, and sometimes its ashy gray color can be distinguished along the rims of the berms.

Soli-Bond is used to bind hazardous chemicals and to prevent them from being washed away. However, it contains toxic materials such as n-hexane and methylcyclohexane; is harmful to aquatic organisms; and is dangerous to inhale. European warning labels state that it is "highly flammable, harmful and dangerous to the environment."[6] Rick had noticed clean-up crews half-draining these pits, mixing up the remaining sludge with Soli-Bond, and then simply plowing the ground over, pit liner and all. These pits were left unmarked; only a discerning, well-trained eye could spot them. "They are creating hundreds of individual, unmarked acres of toxic land where nothing will grow," Rick vented. One of Theo's goals was to determine exactly what sorts of chemicals might be in these pits and to understand what hazards might be left behind in the ground.

Theo had become concerned about fracking after a 2004 Environmental Protection Agency (EPA) study found it to be safe, leading to its exemption from the Safe Drinking Water Act in 2005 (Energy Policy Act 2005).[7] As a result there remains no federal requirement to make public the chemicals used in fracking or to monitor the process for its impact on drinking-water quality. Theo began making a database to document the chemicals used in the oil and gas industry in 2004 when she met Weston Wilson, an EPA whistle-blower. Wilson criticized the EPA study upon which fracking's regulatory exemptions

are based because its authors had significant conflicts of interest. Moreover, he said, the report's analysis relied entirely on industry-supplied data and had involved no field studies (EPA 2004; Wilson 2004).

Theo's interest increased dramatically when she was contacted in 2004 by a Garfield County, Colorado, resident and outfitter, Laura Amos, who had developed a rare adrenal cancer after her domestic water well blew up during a fracking operation. Laura's home was within 900 feet of a well pad. She had come across a document Theo submitted in 2002 to the regional directors of the U.S. Forest Service and the Bureau of Land Management contesting permits issued to drill and frack on the Grand Mesa, in the watershed for the valley where Theo had raised her family.[8] In the letter, Theo noted links between adrenal cancers and a commonly used fracking chemical, 2-BE (2-Butoxyethanol). At the time she submitted the letter, Theo thought it was a local issue and that no one would start reporting health problems from exposure to such chemicals as 2-BE for many years, if ever. She submitted her letter for future generations, rather than for people here and now. But Rick, Laura, and their neighbors' emerging health problems suggested that effects might manifest much sooner than she had thought. With this new and alarming impetus, Theo's research group, TEDX, started its database in 2005, documenting the potential health effects of chemicals used in natural gas extraction. I worked on developing this database with TEDX, and our research had led to this gas-patch tour.

We drove across I-70 to the lush side of Rifle, where irrigation from the Colorado River has allowed fields and farms to grow. Horses graze in fields and there are numerous small ranch houses, a mixture of subdivisions and rural life. Every place we passed had some kind of story for Rick. We headed past the former home of a woman, Chris Mobaldi, who was sick with degenerative neurological problems. She and her doctor linked her illnesses (rashes, blisters, nosebleeds, pituitary tumors, and a very rare neurological condition known as foreign-language syndrome) to exposure to oil and gas chemicals. Paint, exposed to the breezes from nearby wells and pits, had peeled from the side of her house. Her dogs also developed tumors (Mobaldi 2007). She was diagnosed with chemical exposure, so she installed industrial air scrubbers in her home and wore a respirator while outside. Still, she fell ill, forcing the couple to abandon their home without selling it. Chris died in 2010 due to complications from her third surgery for pituitary tumors (Colson 2010b).[9]

We visited one pit that had recently been covered over. Sludge oozed from the corners where the mix had not yet dried. From the pit we could see across

the highway where irrigation and fields had clearly been given up for the production of other resources. Three drill rigs were crowded onto one small, jutting mesa.

A few weeks earlier, Theo and I had taken a flight over this landscape to take a look at the gas patch from above. The pits, roads, and pads are easy to see from the air. They are clear as day, white-yellow lines creeping up the sides of the mesas, terminating in what look like "gopher holes" (figure I.1). The pits could be swimming pools (figure I.2), if they were not out in the wilderness and colored with reds, yellows, and white scum. The relative size of a tanker truck to these three waste pits shows the sheer scale of produced waste fluids (figure I.3).

Further examination of these aerial photos showed one peculiar facility that we could not identify. It included two very large waste pits, but also what looked like an area of straw and rust red about twice as big as the pits (figure I.4). So now we were looking for this site by road, hoping to view it from the ground.

"Let's go take a look over there," I suggested.

"I can take you. It's private property, though," said Rick. "I can't promise we won't be asked to leave."

"Let's give it a shot anyway," Theo chimed in.

We drove under the highway and over to the piece of property we had been viewing from a distance. Rick explained that the owner of this relatively large ranch was lucky to own his mineral rights, potentially easily making him hundreds of thousands of dollars a year from the royalties on his wells.[10] Throughout Colorado, many landowners are in what are known as "split estate" situations in which they own the surface of their land but not the minerals beneath. If an oil and gas company manages to lease the minerals from the mineral rights owner, the company has the right to develop wells on the surface owner's property. Mineral owners are in a much stronger position to negotiate how natural gas is produced from their land. Although this rancher had turned his entire ranch into a gas patch, he was amazingly, according to Rick, still herding his cattle through the land covered by wells, pits, and compressors.

This was an active area. Gleaming white pickup trucks, specialized oilfield services company vehicles, and 18-wheel "water" trucks picked up and removed waste fluids and condensate. Many of these workers would have traveled not from their local homes but from "man camps," migratory labor camps. Despite their name, the man camps also housed some female workers. A local friend of mine, Sandra, a slight, tough-as-nails blonde with a

Stetson hat, had recently taken a job driving a water truck for $80,000 a year, far above what she had been making selling industrial refrigeration units. She took her pit bull and her handgun with her to the man camp and lived there, working 12-hour shifts in the gas patch. Although one of very few women, she told me how she felt right at home in the man camps, having grown up in a gruff, male-dominated mining community. Her stories of people enjoying communal meals painted a very different picture from those in the local newspapers filled with stories of meth-using, sexually and physically violent "roughneckers," a colloquial term for gas and oilfield workers (Farrell 2005; Siegler 2007).

Sandra spent her weeks off back home in her house in the nearest big city, Grand Junction. Grand Junction is where oilfield services companies like Halliburton and Schlumberger house central warehouses for fracking chemical and equipment storage. These companies are contracted by oil and gas companies to perform specialized technical work, particularly fracking operations. There is constant traffic between these central storage areas, the man camps, and the individual wells in development. Red Halliburton and blue Schlumberger trucks loaded with complex machinery are common sights. On that day with Rick, we kicked up dust right along with them, though probably Theo's Prius stood out.

We stopped at each passing facility, trying to build up an on-the-ground anatomy of the gas infrastructure through photos. As we took pictures, Rick explained what things were. Black pipelines, carrying waste fluids, ran all over the arid properties, emptying into pits and separator tanks. We stopped to look at a "flex rig" drill rig, the latest innovation in drilling technology (figure I.5) that can drill at an angle, or even horizontally, from the well pad. This means that one well pad can have many wells that reach out all around into the subsurface. The rig itself does not require many hands because much of the process is computerized. However, human bodies are required to double check that the lengths of pipe fit well together and descend straight. We watched one man attached to a safety wire scale to the top of the gantry (figure I.6). It is precarious and risky work.

We also inspected the pallets of chemicals waiting to be added to the drilling muds: viscous chemical mixtures that keep drill bits lubricated and cool as they cut through rock. Drilling muds also keep the appropriate pressure on a drill bit as it shifts through layer upon layer of rock, each layer requiring higher and higher pressures to cut and stabilize the pressure within the well shaft. They are vital for keeping the tunnel pressurized and keeping force behind the bit.

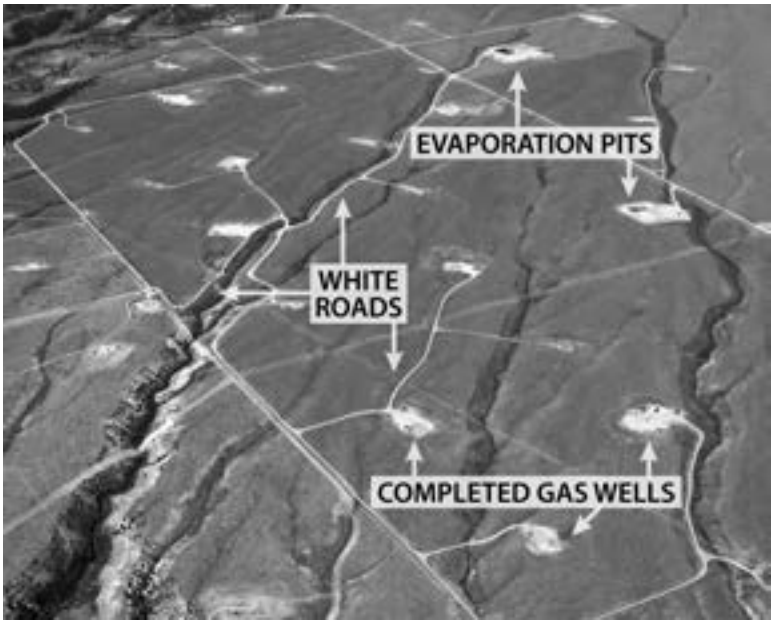

FIGURE 1.1. View of the Rifle, Colorado, gas patch, showing "gopher holes," taken in the summer of 2006. Photo by the author.

FIGURE 1.2. Swimming pools? Various waste pits around Rifle, taken in the summer of 2006. Photo by the author.

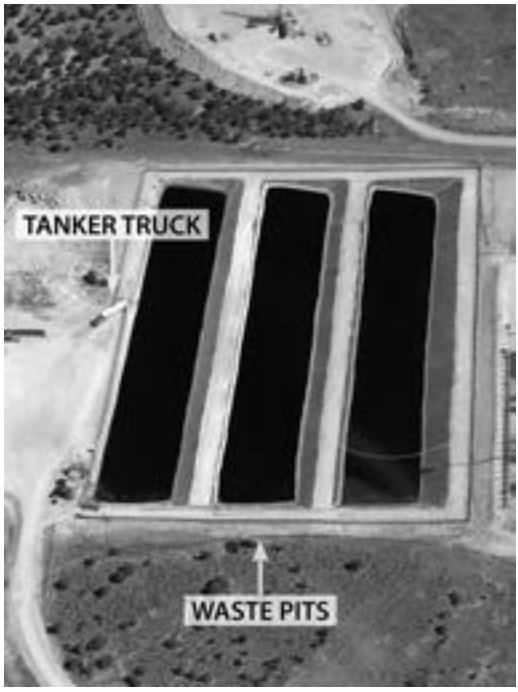

FIGURE 1.3. An 18-wheeler tanker truck (shown for scale) along three waste pits. Photo by the author.

FIGURE 1.4. Photo of a facility we could not identify, summer 2006. Courtesy of TEDX.

FIGURE 1.5. Flex rig for directional drilling. Photo by the author.

FIGURE 1.6. A worker scaling a flex rig. Photo by the author.

We followed lines of black piping from this rig to a large waste pit. Theo recalled that on a previous visit, one of the women with her had suddenly gone blind and developed a crushing headache after breathing fumes from a pit. Had I not known about the potential contents of gas-patch waste, I would have had a hard time seeing it as anything but water reflecting the blue Colorado sky. I strained to smell something incriminating, then concentrated to see if I had a headache. Nothing. "It affects us each differently," Theo said.

Just up the hill, along County Road 246 and through industrial chicken-wire fence, we finally saw the area we had viewed from the airplane. We risked trespassing to take a closer look. Clean-cut guys approached us in big trucks from the bottom of the site as we entered. We explained we were just curious and asked permission to look around. "Sure," they agreed, much to our surprise. As the social controversy in the area about the safety of gas extraction has increased, security around such sites has become much stricter.

A gray-graveled and well-maintained industrial zone stretched downhill into twin waste pits, bigger than two Olympic swimming pools. The views of both the waste disposal site and the valley below were amazing. There were four fountains bubbling away in one pool. Stretching up from the pools, a massive black tarpaulin encased the hillside. A sprinkler system sprouted, row after row, up the hill along the length of the enormous tarp. The tarpaulin formed the backdrop to an industrial irrigation system that, rather that distributing water, sprayed gas-patch wastes up into the air, serving like the fountains to speed the evaporation of the condensate, wastewater, and volatile organic chemicals. The "straw" effect we had seen from the air was actually the crusted orange, red, and yellow residues left by the evaporating wastes. Lisa took pictures of the scene (figure I.7). This industrial fountain on the hillside sprayed waste returned from deep below the earth up into the air. This waste traveled with the wind, over the Colorado River and the I-70 and into homes and bodies, changing the Colorado landscape and its people.

Historical Background and Theoretical Significance

What is happening in this landscape? Why does Rick think gas drilling is making him ill? How is Colorado's social, physical, and legal landscape being transformed in the early 21st century by drilling for natural gas? How do the dynamics of this natural gas boom relate to those of other extractive industries that have shaped the social and environmental history of this region (BBC Research and Consulting 2008; Casselman 2008; Colorado School of

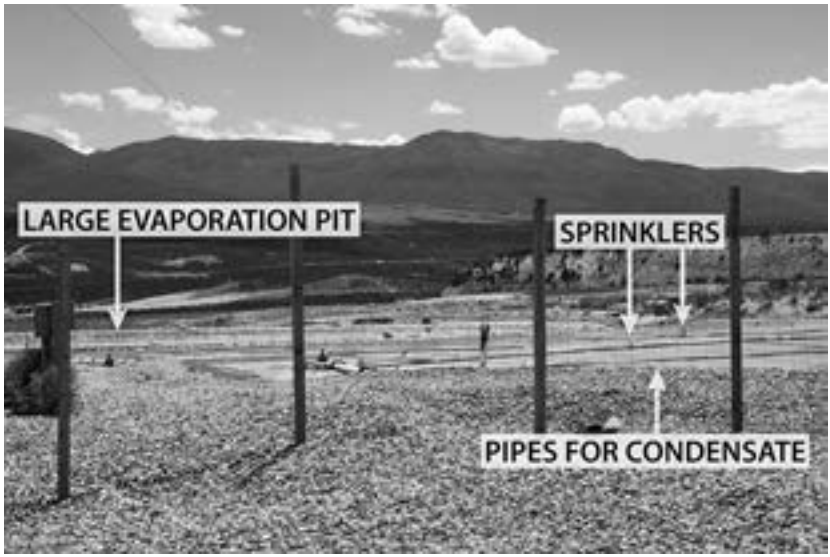

FIGURE 1.7. A waste pit seen up close, summer 2006. Courtesy of Earthworks.

Mines 2009)? What might studying this natural gas boom tell us about the contemporary fossil-fuel industry in the age of what scholars have variously characterized as "post-modernity," "globalization," "late" or "millennial capitalism," and the "Anthropocene," especially given that the boom-bust cycles of fossil-fuel extractive industries are classically "modern" problems (Yergin 1991; Black 2000; Comaroff and Comaroff 2000; Crutzen and Stoermer 2000)?

This book follows the efforts by people across the United States (scientists, journalists, lawyers, gas-patch residents) to make visible and actionable the damaging changes produced by the recent U.S. boom in natural gas extraction. Making such impacts legally, scientifically, and socially apparent is no easy business, just as it is no easy business to locate and bring to the surface a flammable, odorless gas from miles below ground, gather it in pipes, and circulate it thousands of miles across the country to power factories, fuel buses, and light stoves, as well as generate electricity and petrochemicals. This book examines how the processes of visualizing, extracting, transporting, marketing, and valuing natural gas strategically make the problems of people like Rick invisible. It also examines and develops novel scientific and social scientific tools for combating that invisibility.

The gas-patch trip described here can now be taken all over the United States in one form or another: in suburban Ohio and rural Pennsylvania, in New Mexico, California, Texas, Louisiana, and Michigan. While fracking's wide-scale application to extracting gas from shale is necessary for the present gas boom, it is not the only activity that opened up this new energy frontier (Colorado School of Mines 2009). To track the variety of activities—scientific, geological, chemical, social, political, national, regional, economic, cultural, corporate—that made this new frontier, this book draws on the history and theory of science and technology development, employing ethnographic fieldwork as its primary method. I am particularly interested in the role that contemporary science and technology played in producing—as well as resisting—the creation of this frontier. I analyze how relationships between corporations and the academy, together with state, local, and federal agencies, aligned to speed the extraction of natural gas. I show that this alignment has a series of social and organic consequences. To understand what I term the "chemical bonds" that tie Rick's illnesses to his environmental conditions, this book examines new ways to map and unsettle "corporate bodies"—those networked and peopled, physical and environmental assemblages that are presently creating the global oil and gas industry.

This story is not unique. The dynamics of the gas boom are similar to those that have occurred and are occurring in extractive industries the world over. They include environmental transformation and destruction, social destabilization, and structural and physical violence (Appadurai 1990; Nash 1993; Coronil 1997; Peluso and Watts 2001; Watts 2003; Sawyer 2004; Tsing 2004; Ferguson 2005, 2006; Ong and Collier 2005; Santiago 2006; Zalik 2004, 2008, 2009).[11] Historians, anthropologists, and activists have endeavored to describe such dynamics since the first use of oil and gas for illumination, and then as fuel, replacing coal and transforming humanity's capacity to produce mechanical work, speed, heat, and light (Yergin 1991; Black 2000). It is hard to overstate the importance of fossil fuels to contemporary human life; their very necessity and integration into every aspect make their scale and importance nearly impossible to see unless some crisis interferes with supply. Any really serious restriction of supply could rapidly cause basic services such as air, car, and train travel, as well as the defense industry, electricity, and petrochemical production to collapse. Since World War I, much of international foreign policymaking has aimed at preventing any such event. From the perspective of fossil fuel–dependent industries, the resulting policies have been quite successful (Yergin 1991).[12]

This book draws from four fields in order to situate the ethnography of natural gas extraction in this massive industry: environmental history, postcolonial anthropology, science and technology studies (STS), and digital-media studies.[13] Each field offers theoretical tools, case studies, and methods that, when combined, offer novel ways to analyze and intervene in the complex social, physical, and academic terrain of the oil and gas industry. Since the current natural gas boom depends on the use of fracking by oilfield services companies, and the health effects of chemicals used in this process are controversial, this book also speaks to the larger issues of toxic chemicals and environmental health. It combines theory and case histories from environmental history, anthropology, and STS to argue for new digital-media approaches to studying both chemicals and corporations in order to improve regulatory, social, and scientific methods for identifying and addressing emerging environmental health issues.

Chapter Previews

I begin by examining how the chemical bonds forged in the natural gas extraction process are being revealed by emerging forms of "civic science." Anthropologists Kim and Mike Fortun coined this term to analyze the emergence of forms of epidemiology and toxicology that seek to counter the influence of corporate science and, frequently, the corporate production of manifestly ideological knowledge about matters of scientific and social concern (Brown and Mikkelsen 1997; Fortun 2001; Allen 2003, 2004; M. Fischer 2003, 2009; Fortun and Fortun 2005). I trace the construction and influence of a database collaboratively built and distributed by scientists, landowners, whistle-blowers, and advocacy organizations to illustrate the potential human and environmental health effects of chemicals used in natural gas extraction. I follow how this database helped to identify natural gas extraction as a potentially massive public health threat, leading to a congressional inquiry into the practice, Oscar and Golden Globe–nominated documentaries, and moratoriums and bans on natural gas drilling (Waxman 2007; Fox 2010, 2013; Lustgarten 2014). Mapping and understanding connections between chemical exposures and illnesses is further advanced, this book argues, when we use participatory interactive digital tools designed to help communities struggling to understand extractive industries.

Rarely are these communities able to collectively shape the extractive process. We lack a process for studying and responding to the impacts of multi-

national corporations at the level of individual and community health. Here, I expand on Fortuns' notion of civic science by experimentally developing new media for public-interest science: for example, digital databases that enable collaborative community and academic research about infrastructural industries such as the oil and gas industry with the aim of improving communities' ability to shape extractive industries. Such participatory and recursive databases could act as a vital medium for civic science by cultivating corporate accountability, regulatory efficiency, and effective public engagement in shaping energy extraction and academic relevance (Kelty 2008).

Chapter 1 looks at the history of how fracking came to be exempted from the Safe Drinking Water Act in 2005. It illuminates how specific information, spaces, and people were sequestered in order to enable a boom in natural gas extraction using fracking. The United States' natural gas development frontier emerges from and builds upon this sort of enclaving tactic (Bowker 1994; Ferguson 2005, 2006; Watts 2005; Santiago 2006). My discussion of landowner stories and events experienced in western Colorado illustrates how these tactics initially made it impossible to link emerging illnesses to the chemicals used in natural gas extraction.

Chapters 2 and 3 explore the longer history of petrochemical industries, which actively underdevelop and hinder the environmental health sciences from connecting environmental exposures to illnesses through their use of shared corporate strategies, investment in particular modes of science, public relations, and political influence. I analyze how the environmental illnesses and damage produced by these industries have been systematically rendered hard to study. Chapter 2 examines Colborn's work historically to analyze how she developed research methodologies and social strategies that unsettled the "regimes of imperceptibility" around the ability of industrial chemicals to disturb hormonal signaling, producing the field of endocrine disruption research. I take the term "regimes of imperceptibility" from Michelle Murphy's study (2006) of Sick Building Syndrome, and I explore scientific and later social scientific methods to undo them.

Chapter 3 examines how Colborn applied her effective research methodologies for databasing and social strategies to form her novel science-advocacy organization, TEDX. TEDX maintains a database of all publications about endocrine disruption, and it develops research reports for policymakers, scientists, and advocacy organizations to help reduce exposure to, and impacts of, endocrine disruptors. Ethnographic analysis of the database provides material with which to examine the relationship between corporations and social movements in the context of contentious scientific policy debates

in the United States over energy resources. Building on Kim Fortun's notion of "informating" environmentalism, I identify the development of a mode of civic scientific research that I call health environmental impact response science, or HEIR science (Fortun 2004; Fortun and Fortun 2005), influenced by Colborn's research model for studying endocrine disruptors. HEIR science (or HEIRship) recognizes how chemicals form and transform relationships across species and across generations within species by making use of familial resemblances across species, such as shared biochemical signaling pathways (e.g., the estrogen receptor) and shared ecological positions in food chains.[14] Recognizing chemicals as a biocultural inheritance that ties together human and environmental health by potentially transforming the biology of future generations requires public and regulatory attention to the unpredicted hazards produced by synthetic chemistry. HEIRship is made more challenging due to the academic, regulatory, and economic capital of chemical production and consumption industries. In response, new research infrastructures such as TEDX and their database of research on endocrine disruption are growing.

Chapter 4 examines how TEDX and Colborn's HEIRship led to their examination of the emerging local health problems related to the chemicals used in natural gas extraction. I analyze how Colborn's database of the potential health effects of chemicals used in gas extraction is being employed as a map in order to transform people's perspectives on the effects of natural gas development. TEDX's database allows landowners to relate their diverse illnesses and experiences to natural gas development. It provides predictive maps of health problems related to chemicals, and it also articulates how holes in scientific data and regulatory oversight make the environmental human health impacts of fracking hard to study. I illustrate how TEDX and its collaborators successfully sparked a scientific and social controversy about the chemicals used in fracking.

Connecting chemical exposure and illnesses needs detailed validation and is challenging scientifically and socially. Interactive online tools for popular epidemiology, mapping incidents, local circumstances, and the spread of industry tactics (Brown and Mikkelson 1997) can further address these challenges. Chapter 5 begins to analyze whether online participatory mapping and databasing tools can provide new ways to transform community relations with extractive industries beyond the specific practice of fracking. Given the historical interrelationship between these industries and the academy, I examine the need for an engaged or "activist" social science that actively works to develop civic infrastructures. Among other things, these infrastructures can help communities potentially impacted by extractive in-

dustries to collect and keep in the public domain information about illnesses, toxicities, water quality, spills and leaks, aquifer protection, and experiences elsewhere. In general, they can provide the information necessary for an informed citizenry. I name this novel branch of STS, enabled by digital media, "STS in practice": engaged social scientific research that actively involves communities, scientists, and engineers in transforming the processes of scientific research and technology development. It aims to reduce power asymmetries that persist and pattern scientific inquiry, and that are embedded in technical infrastructures. Tools developed by STS in practice, I argue, can increase the industry's social, environmental, and legal accountability.

Chapter 6 methodologically grounds the development of STS in practice by introducing the work of a research group called ExtrAct. ExtrAct's primary project was to develop web tools for the oil and gas patch communities. Digital media tools mapping pipelines, spills, and wells have become commonplace since ExtrAct.[15] ExtrAct was in many ways ahead of its time, providing the first interactive, online map, for instance, of oil and gas wells in five different states (WellWatch), a tool for evaluating and sharing interactions with industry employees (Landman Report Card), and an online platform for sharing news about oil and gas development (News Positioning System). The tools, unlike many that have followed, were specifically designed to both facilitate information sharing and build online community in accordance with the larger goal of this Knight Journalism Foundation–funded center which, under Chris Csikszentmihályi's directorship, was to develop new forms of "civic media" by using digital media.[16] This chapter describes how by combining participatory design practices with ethnographic fieldwork involving community organizations, NGOs, environmental scientists, and lawyers, ExtrAct co-conceptualized and developed a set of online databasing and mapping tools in order to link communities managing issues related to the oil and gas industry.

Chapter 7 studies the technical issue of how to develop open-source, open-access online tools for community organization in a contentious and polarized field like that of natural gas development. Separating the front-end website design and development from back-end or code development, this chapter looks at the difficulties of developing tools that can adequately protect users of ExtrAct websites and also fulfill the websites' goals of increasing industry accountability and community awareness.

Chapter 8 examines ExtrAct's back-end database development ethnographically. It explores how databases can be designed so that nonprogrammers can become involved in supporting and extending online databases they

use, without requiring them to become proficient in coding. Designing for participatory development of database infrastructure extends models of community formation developed in open-source software communities to generate participatory databasing and mapping tools for grassroots monitoring of the oil and gas industry.

Chapter 9 evaluates the use of the ExtrAct tools, particularly WellWatch, a wiki-based tool for community monitoring of the oil and gas industry. This chapter analyzes WellWatch's efficacy as a platform for multisited ethnography and discusses its potential benefits for both communities and academics.

Chapter 10 memorializes Theo Colborn by theorizing the "fossil-fuel connection" between natural gas and petrochemicals (Colborn 2014). It examines how these two industries need to be studied together in order address the twin challenges of endocrine disruption and climate change.

Throughout this book I analyze the interrelationships among the oil, gas, and chemical industries, whose vast social, political, and environmental influences come together within the bodies of landowners like Rick. The book's conclusion revisits Rick's story to systematically draw together the book's theoretical and methodological interventions. Rick and the other landowners I describe in this book struggle to connect their illnesses to these industries in part due to scientific, regulatory, technical, and social structures developed in the service of industry imperatives. These industries remain unaccountable. They are also inseparable in our fossil fuel–dependent economy. Oil, gas, and petrochemicals produce a vast range of products from fuel to fertilizer and pesticides that are central to our industrial economies (Kamalick 2009; IHS 2011). To understand and account for our corporate bodies and chemical bonds, we need to develop new forms of science and social science that can keep up with the legal, social, and technical changes that enable them and that create blindness to many trade-offs and costs erased from corporate accounting sheets and business plans. TEDX and ExtrAct are situational responses to the impact of the contemporary boom in natural gas extraction. ExtrAct's STS in practice and TEDX enable new forms of social science involving civic science, interactive media, and informed social movements to build and strengthen empirical databases and explanatory models that stand up to scientific and legal challenges, offering new modes of monitoring the environmental health of our communities as well as our bodies.

NOTES

As WellWatch and Landman Report Card are no longer online, materials from these websites can be found on Sara Wylie's website: https://sarawylie.com/publications/fractivism-corporate-bodies-and-chemical-bonds/.

Preface

1. Chapter 1 further discusses the chemistry of these fracking fluids. More thorough reviews of the history of fracking can be found in Montgomery and Smith (2010) and Shellenberger and colleagues (2012).

Introduction

1. *Condensate* refers to liquid hydrocarbons that can be produced along with natural gas. Here Rick was using the term more generally to refer to natural gas waste fluids, including frack fluid or condensate that might be mixed with chemicals used in fracking.

2. Throughout this book I mix pseudonyms for those who wished to be de-identified with the real names of those who have consented to be identified in order to protect the identities of those who prefer to remain anonymous. Most of the people and places whose stories are included in the book are widely known and published in other materials.

3. Colborn died on December 14, 2014. Chapter 10 reflects on her passing and the lasting consequences of her work on the health impacts of fracking. Additionally in 2016 I coauthored an article, "Inspiring Collaborations," with Deborah Thomas, Kim Schultz, Susan Nagel, and Chris Kassotis, reflecting on Colborn's cross-disciplinary influence.

4. The phrase *little, yellow, different* is an advertisement tagline for a painkiller that was satirized in the cult movie *Wayne's World*.

5. OGAP was founded in 1999, and it merged with Earthworks in 2005. http://www.earthworksaction.org/about.

6. The material safety data sheet for Soli-Bond was received from Rick Roles via https://web.archive.org/web/20040610174459/http://www.toxic-totnes.org.uk/thechemicals.html.

7. This exemption has been colloquially termed the "Halliburton loophole" as chapter 1 investigates.

8. Colborn (2007), appendix A, page 4.

9. For more on this story from the perspective of her friend and colleague, see Meixsell (2010).

10. It is hard to know exact royalty rates. It depends on contract terms and minerals rights ownership. There is an avid royalty rumor mill about earnings, but it's hard to get to the truth of such claims.

11. Resource extraction is historically tied to underdevelopment. Academic research on underdevelopment begins with Walter Rodney's seminal study *How Europe Underdeveloped Africa* (1972). Ferguson (1994) and Comaroff and Comaroff (2000) further explore the relationship of neoliberal capitalism to African underdevelopment. This anthropology and critical theory tradition counters economics discourse describing Africa and the Middle East as "resource cursed" and unable to fully appropriate the rents of their mineral resources due to in-country political corruption (Auty 1993; Ross 2006; Humphreys, Sachs, and Stiglitz 2007) and advising free-trade and democratic development to improve such nations' economic positions. These arguments do not account for why gas and oil development flourishes in the most politically unstable, brutal, and undemocratic "developing" nations (Ferguson 2005, 2006). An examination of how oil and gas extraction sites are separated from the surrounding social, economic, and physical landscapes through corporate and nationally controlled enclaves reveals how lucrative extractive industries' violent creation and protection of stable environments for extraction succeed in and depend on destabilizing other local economies, social relationships, and land traditions (Bowker 1987; Peluso and Watts 2001; Hodges 2004; Ferguson 2005, 2006; Santiago 2006). Watts (2003, 2005), Ferguson (2005), Watts and Kashi (2008), and Appel (2011) further develop oil and gas extraction's relation to the destabilization of democratic development and the continuing legacies of underdevelopment, particularly in regions of resource extraction.

12. There is insufficient space to thoroughly discuss the history of natural gas or oil development. Indeed it is frequently hard to separate the two industries as they co-developed. However, there is a small historiography on the gas industry that centers on the relative invisibility of this fuel as opposed to oil in terms of political, popular media, and academic attention (Castañeda 1993, 1999; Castañeda and Smith 1996). It is interesting to note that the term *natural gas* was first developed to refer to gas extracted from the ground rather than gas "produced" through the biological decay of waste and piped into cities in the early industrial era for illumination.

13. Environmental history is a branch of history that investigates how physical environments of water, air, and earth are actively shaped by human habitation (and vice versa). For a review of the literature in environmental history, see Worster (1990, 1992), Cronon (1995), Steinberg (2002), and Stine and Tarr (1998).

14. The suffix *–ship* when appended to a noun forms a new noun that indicates the possession of a state or condition, i.e., fellowship or the possession of a craft or a skill, i.e., scholarship (see the *Oxford English Dictionary*).

15. For instance, the nonprofit organization FracTracker maintains a map of oil and gas wells throughout the United States: https://www.fractracker.org/map/. Harvard

University maintains a similar map of fracked wells: http://worldmap.harvard.edu/maps/FrackMap. The Natural Resources Defense Council maintains a map of pipeline spills: https://www.nrdc.org/onearth/spill-tracker. Earth Justice maintains a map of fracking related accidents and spills across the United States: http://earthjustice.org/features/campaigns/fracking-across-the-united-states?gclid=Cj0KEQjw9r7JBRCj37PlltTskaMBEiQAKTzTfDpIJDEKcTo4VqsBT81KQY7BbMaIg55qgtGo_izH6lIaAoKS8P8HAQ.

16. The center has since changed directorship and been renamed the Center for Civic Media. See https://civic.mit.edu/.

1. Securing the Natural Gas Boom

An earlier version of this chapter appeared in Appel, Mason, and Watts (2015).

1. http://www.slb.com/about.aspx.

2. https://web.archive.org/web/20140608141053/http://www.slb.com:80/about/who.aspx.

3. Oilfield services companies early in their development established noncompete principles that they would never directly compete with oil majors by leasing and developing minerals (Bowker 1994).

4. For more on the history of fracking, see Cooke et al. (2010).

5. Micro-seismic measurement sensors are placed in wells adjacent to the well being fracked in order to "listen" to and interpret the direction and spread of fractures as they form (Shellenberger 2011).

6. Popular accounts of the fracking boom tend to stress the role of independent wildcatters over big companies and federal funding (Zuckerman 2013). However, more detailed historiographic work shows that federal funding was vital for the development of fracking and horizontal drilling (Shellenberger et al. 2012). Additionally, though fracking enabled small companies to participate in the U.S. boom, the oilfield services companies involved such as Halliburton and Schlumberger are the world's largest and oldest.

7. Earthworks, "Hydraulic Fracturing—What It Is," https://web.archive.org/web/20171013102856/https://www.earthworksaction.org/issues/detail/hydraulic_fracturing_101#.Wf-w9RNSzEZ; Earthworks, "Acidizing," http://www.earthworksaction.org/issues/detail/acidizing#.U4I_3C8inBM.

8. Research on chemicals used in fracking was part of Northeastern University's Hydraulic Fracking Research Cluster. An undergraduate chemistry student, Bakkar Hassan, researched the use of acids, surfactants, corrosion inhibitors, and oxidizers as part of this group.

9. Here intellectual property was protected, as opposed to the physical property of pipelines and wells investigated in Watts's work in Nigeria (Watts 2005). However, in the United States, developing scientific research favorable to the industry achieved a similar result to the use of physical force in Nigeria and the continued development of fossil-fuel resources.

10. MIT Executive Education Program, "Schlumberger Building a Dialogue for Innovation," https://web.archive.org/web/20100609151900/http://mitsloan.mit.edu/execed/pdf/schlumbergercasestudy.pdf.