HYDROFRACKING

WHAT EVERYONE NEEDS TO KNOW®

ALEX PRUD'HOMME

HYDROFRACKING

WHAT EVERYONE NEEDS TO KNOW®

This page intentionally left blank

HYDROFRACKING

WHAT EVERYONE NEEDS TO KNOW®

ALEX PRUD'HOMME

OXFORD
UNIVERSITY PRESS

OXFORD
UNIVERSITY PRESS

Oxford University Press is a department of the University of Oxford.
It furthers the University's objective of excellence in research, scholarship,
and education by publishing worldwide.

Oxford New York
Auckland Cape Town Dar es Salaam Hong Kong Karachi
Kuala Lumpur Madrid Melbourne Mexico City Nairobi
New Delhi Shanghai Taipei Toronto

With offices in
Argentina Austria Brazil Chile Czech Republic France Greece
Guatemala Hungary Italy Japan Poland Portugal Singapore
South Korea Switzerland Thailand Turkey Ukraine Vietnam

Published in the United States of America by
Oxford University Press
198 Madison Avenue, New York, NY 10016

Library of Congress Cataloging-in-Publication Data
Prud'homme, Alex.
Hydrofracking / Alex Prud'homme.
pages cm—(What everyone needs to know)
Includes bibliographical references and index.
ISBN 978–0–19–931125–5 (pbk. : alk. paper)—ISBN 978–0–19–931126–2
(cloth : alk. paper) 1. Hydraulic fracturing—Popular works.
2. Shale gas reservoirs—Popular works. 3. Oil wells—
Hydraulic fracturing—Popular works. I. Title.
TN880.2.P78 2013
622'.3383—dc23
2013028962

1 3 5 7 9 8 6 4 2
Printed in the United States of America
on acid-free paper

CONTENTS

Part III Hydrofracking: Today and Tomorrow

GLOSSARY

acid. A generic term used to describe a treatment fluid typically comprising hydrochloric acid and a blend of acid additives.

annulus. The space between a casing string and the borehole or between two casing strings.

aquifer. A water-bearing stratum of permeable rock, sand, or gravel.

biocide. An additive that eliminates bacteria in the water that produce corrosive byproducts.

blender. The equipment used to prepare the slurries and gels commonly used in fracture stimulation treatments.

borehole. A hole drilled into the earth by people in search of natural gas and oil.

breaker. An additive that reduces the viscosity of fluids by breaking long-chain molecules into shorter segments.

CAS. Chemical Abstract Service, a division of the American Chemical Society, whose objective is to find, collect, and organize publicly disclosed substance information.

CAS number. A unique number assigned by the CAS that identifies a chemical substance or molecular structure.

The List compiled from FracFocus: http://fracfocus.org/glossary of terms, and the State of California, Department of Conservation website: http://www.conservation.ca.gov/index/Pages/glossary-frk.aspx

casing. Pipe placed in an oil or gas well to (1) prevent the wall of the hole from caving in; (2) prevent movement of fluids from one geologic formation to another; (3) provide a means of maintaining control of formation fluids and pressure as the well is drilled.

casing string. Pipe that lines a well after it has been drilled. It is formed from sections of tube that have been screwed together.

collapse strength of casing. The pressure necessary to collapse a well casing, tubing, or drill pipe inside a well. The collapse strength of casing can be calculated from the yield strength of the metal and diameter of and wall thickness of the casing, tubing, or drill pipe.

conductor casing. Generally, the first string of casing in a well. It may be lowered into a hole drilled into the formations near the surface and cemented in place, or it may be driven into the ground by a special pile driver. Its purpose is to prevent the soft formations near the surface from caving in and to conduct drilling mud from the bottom of the hole to the surface when drilling starts. (Also known as "conductor pipe" and "drive pipe.")

casing shoe. A tapered, bullet-nosed piece of equipment often found on the bottom of a casing string. The device guides the casing toward the center of the borehole and minimizes problems associated with hitting rock ledges or washouts as the casing is lowered into the well. (Also known as a "guide shoe.")

cement. A mixture of sand, water, and a binding agent with no aggregates.

Cement Bond Log. A geophysical log that graphically displays the bond between cement and casing.

clay stabilizer. An additive that prevents clays from swelling or shifting.

conductor casing. The first casing string placed in a borehole. The purpose of the conductor is to prevent the collapse of the hole in unconsolidated material, such as soil.

corrosion inhibitor. An additive used in acid treatments to prevent corrosion of pipe by the corrosive treating fluid.

cross-linker. An additive that reacts with multiple-strand polymers to couple molecules, creating a fluid of high but closely controlled viscosity.

Darcy's Law. The mathematical equation that quantifies the ability of fluid to flow through porous material such as rock.

data van. The truck used to monitor all aspects of the hydraulic fracturing job.

DOE. The US Department of Energy.

drilling rig. The equipment used to drill the borehole.

EPA. The US Environmental Protection Agency.

EPCRA. The Emergency Planning and Community Right to Know Act. In 1986, Congress enacted EPCRA, a statute that established requirements for federal, state, and local governments, tribes, and industry regarding emergency planning and community right-to-know" reporting on hazardous and toxic chemicals. One provision of EPCRA remains highly controversial. As the EPA notes, "All information submitted pursuant to EPCRA regulations is publicly accessible, unless protected by a trade secret claim."

frac tank. The container used to store water or proppant that will be used for hydraulic fracturing.

friction reducer. An additive used to reduce the friction forces on tools and pipes in the borehole.

gelling agent. An additive that increases the viscosity of a fluid without substantially modifying its other properties.

groundwater. Water in a saturated zone under the earth's surface.

GWPC. Ground Water Protection Council.

hydrology. The study of the flow of water.

intermediate casing. Provides protection against caving in of weak or abnormally pressured formations and enables the use of drilling fluids used to drill into lower formations.

intermediate casing string. The string of casing set in a well (after the surface casing but before production casing is set) to keep the hole from caving in and to seal off formations. In deep wells, one or more intermediate strings may be required.

IOGCC. Interstate Oil and Gas Compact Commission.

MSDS. Material Safety Data Sheet.

mechanical integrity. The measure of a well's casing, tubing, packer, and cement to contain fluids traveling up and down the well without the fluids leaking into surrounding geologic formations.

natural gas. Methane CH_4 (with or without impurities such as nitrogen). Natural gas is often classified as either biogenic (of biological origin) or thermogenic (of thermal or heat origin).

NGWA. National Ground Water Association.

nonfreshwater fluids. Water with total dissolved solids (TDS) of greater than 3,000 parts per million (ppm) or any other fluid used in oil and gas production, including hydraulic fracturing fluids.

other cement evaluation method. Used to determine the quality of the cement bond between a well's casing and the geologic formations surrounding a borehole.

o**xygen scavenger.** An additive that prevents corrosion of pipes by oxygen.

packer. A downhole device used in completions to isolate the casing-tubing annulus from the production conduit, enabling controlled production, injection, or treatment.

perforate. To pierce holes in the casing and cement in a well to allow formation fluids, such as oil and gas, to enter into a well and to allow fluids to be injected into a geologic formation. Perforating is accomplished using a perforating gun, or perforator.

perforated interval. A section of casing that has been perforated during hydraulic fracturing.

permeability. The quantification of how easily fluids, such as oil, gas, and water, flow through the pore spaces in a geologic formation and into the borehole. Rocks have vertical, horizontal, and tangential permeability.

pH adjusting agent. An additive that adjusts the acidity/alkalinity balance of a fluid.

Poisson's ratio. A mechanical property that can be used to predict the direction in which fractures will occur in a given geologic formation.

When a geologic formation is compressed in one direction, it tends to expand in the other two directions perpendicular to the direction of compression. This phenomenon is called the Poisson effect.

production casing. The casing string set near the bottom of a completed borehole through which oil or natural gas is produced.

proppant. A granular substance (sand grains, crushed walnut shells, aluminum pellets, or other material) that is carried in suspension by the fracturing fluid. Proppant keeps fractures open in a formation when fracturing fluid is withdrawn after a fracture treatment.

radial cement evaluation log. A continuous log (graph) created by running a sonic transmitter and receiver down a well to determine the quality of the cement bond between the casing and the geologic formations surrounding a well.

reservoir. A bed of rock containing oil or natural gas.

reverse engineering. The reproduction of a product, through analysis of its structure, function, and operation.

saturated zone. The subsurface zone where the interstitial spaces of rock are filled with water.

shale. A fine-grained sedimentary rock that may contain oil or natural gas but which may not be producible naturally.

site. The location of a well including the area used for fluid storage and well treatment.

spring. The intersection of groundwater and surface water.

surface casing. The casing string set below freshwater aquifers to prevent their contamination.

surfactant. A chemical that acts as a surface active agent. This term encompasses a multitude of materials that function as emulsifiers, dispersants, oil-wetters, water-wetters, foamers, and defoamers.

total dissolved solids (TDS). The total amount of solids, such as minerals, salts, or metals, that are dissolved in a given volume of water.

toxicology. The study of symptoms, mechanisms, treatment, and detection of poisoning.

TRI. Toxic Release Inventory.

true vertical depth. The vertical distance from a point in the well (usually the current or final depth) to the surface.

tubing. A small-diameter pipe that is run inside well casing to serve as a conduit for the passage of oil and gas to the surface. Tubing can be a permanent or temporary part of the borehole.

tubing strings. The entire length of tubing in a well.

unsaturated zone. The subsurface zone where the interstitial spaces of rock contain but are not completely filled with water.

vadose zone. The subsurface zone between the surface and the unsaturated zone through which water travels.

Variable Density Log. The geophysical log that is a graphic representation of the bond between the cement and the borehole.

well. The hole made by the drilling bit, which can be open, cased, or both. Also called borehole, hole, or wellbore.

wellbore. A borehole; the hole drilled by a drill bit; also called a borehole or hole.

well stimulation. Any of several operations used to increase production by increasing the permeability of an oil- or gas-bearing formation, such as acidizing or hydraulic fracturing.

Young's modulus. Used in drilling, it is a measure of the stiffness of elastic of a geologic formation, defined as the ratio of the stress along an axis over the strain along that axis. Young's modulus can help determine how wide fractures are likely to be in a formation that will be hydraulically fractured.

PREFACE: WHY I WROTE THIS BOOK

I was first confronted by the intense emotions around hydrofracking at a public meeting in New York City in November 2009. It was a cold, blustery night in downtown Manhattan, but over a thousand people streamed into a high school auditorium to learn about the potential benefits and hazards of extracting natural gas from in and around the city's upstate watershed. I was there to research my book, *The Ripple Effect: The Fate of Freshwater in the Twenty-First Century*, and was curious to know what impact hydrofracking might have on the quality and quantity of the drinking water supplied to over nine million people every day.

The debate that night centered on the Marcellus Shale, which is a 95,000-square-mile swath of gas-rich rock that underlies parts of five states: New York, Pennsylvania, Maryland, West Virginia, and eastern Ohio. The stakes in play there—financial, environmental, political, and social—are enormous. The Marcellus deposit is thought to be the single largest energy deposit in the United States, and the second-largest gas deposit in the world (after the South Pars/North Dome gas-field, shared by Qatar and Iran). The Marcellus is estimated to contain at least 500 trillion cubic feet of natural gas, which is enough to power all American homes for 50 years.[1]

Shale is a dense layer of sedimentary rock that lies a mile or more underground in deposits sprinkled across the country (and, indeed, around the world). Natural gas or oil trapped in shale formations is known as "shale gas" or "shale oil," and is chemically identical to gas and oil taken from traditional wells. Geologists have known about shale reserves for years, but until recently they have been too difficult to access. In the last decade, however, industry and government groups have pushed a technology called hydraulic fracturing, or "fracking," which has unlocked enormous quantities of shale oil and gas and set off an environmentalist backlash.

Hydrofracking has created jobs, spurred industry, lowered carbon emissions, and provided an economic boon to many communities across the country. (While there is great interest in the technology worldwide, hydrofracking has been commercialized only in North America thus far.) Yet, while the temptations of "fracked" energy are great, critics say that it pollutes the water, ground, and air, and that these costs outweigh its benefits.

It was against this backdrop that I attended the meeting in New York City in 2009. The large auditorium was packed to standing-room only that night. Roughly a quarter of the crowd supported hydrofracking; another quarter had not made up their minds; and the remaining half were opposed. Some attendees wore suits or high heels, some came in camouflage and blue jeans, others were dressed up as mountains, fish, or rivers. Red-faced politicians stirred the crowd with fiery rhetoric; state regulators and energy executives kept a low profile; journalists swirled around the auditorium; and citizens asked pointed questions.

When gas companies began to explore rural upstate New York in the early 2000s, many residents leased their property for modest fees. Some were paid as little as $3 per acre plus a 12.5 percent royalty; by 2007 lease prices averaged about $25 an acre, plus royalties of 12.5 percent; by 2009, prices had skyrocketed to $6,000 an acre, plus royalties of 20 percent.[2] The region was mired in an economic slump, and many residents and businesses were pushing then-governor David Paterson to open state-owned land to hydrofracking to generate jobs and revenue. But Michael Bloomberg, mayor of New York, cautioned that fracking "is not a risk that I think we should run."[3]

Since that night in 2009, the two sides have only become more polarized. In New York State, for example, the public remains almost evenly split on the issue, with 39 percent in favor of hydrofracking and 43 percent opposed to it, according to a 2013 Siena poll.[4] The *Wall Street Journal* opines, "fracking could be the difference between economic life and death" for New York.[5] But celebrity opponents, like Yoko Ono and the actor Mark Ruffalo (who lives in upstate New York), shoot back, "You can't say that we have climate change and we have to fight it, and then... say we're going to move forward with hydrofracking.... You can't have both."[6] And "Fracktivists" note that if fracking fluids—some of which are toxic or carcinogenic (as is benzene)—pollute the city's carefully protected watershed, New York will be forced by EPA regulations to build a $10 billion filtration plant that will cost taxpayers millions of dollars a year to operate.[7]

Current New York governor Andrew Cuomo has no easy answers. Hydrofracking advocates, such as the Joint Landowners Coalition of New York, have pressured state legislators to approve the process for nearly five years, and complain that Cuomo is stalling.[8] But opposition groups threaten to label Cuomo—who is said to have presidential ambitions—a traitor and sellout if he allows hydrofracking.[9] Cuomo was given a momentary reprieve in early 2013. The day before state regulators were set to issue an environmental impact statement, the state Department of Health requested more time to review three new studies. The state assembly imposed a two-year moratorium on new hydrofracked wells to await results of the studies.[10]

The argument in New York mirrors the national dispute over hydrofracking, and foreshadows a worldwide debate as shale gas and oil become increasingly important to the global energy equation.

In the meantime, my own position on hydrofracking continues to evolve. In 2009, informed by my research into water-related issues, I was opposed to hydrofracking. There is little question that the process is inherently risky: it uses huge volumes of water and has set off local "water wars" in arid states such as Colorado, Texas, and California. Moreover, shale wells can pollute the air and groundwater. Once hydrofracked, each well generates millions of gallons of toxic wastewater, which includes secret chemical mixtures and naturally occurring radioactive elements that are difficult to clean and sequester. As hydrofracking technology spreads around the world, these challenges will become exponentially more difficult.

Yet the technology, practice, and oversight of hydrofracking have advanced since 2009, and it has become difficult to ignore the benefits of shale fuels. The scientific consensus holds that natural gas burns more cleanly than coal or oil, and thus reduces greenhouse gases; the economic consensus holds that hydrofracking creates jobs, revenue, and new supplies of energy; and the political consensus holds that natural gas is an effective "bridge fuel" to tide us over until renewable energy sources—such as wind, solar, geothermal, and hydropower—have been commercialized.

To put it bluntly, hydrofracking is neither all good nor all bad. Rather, it is a timely and important subject rendered in shades of gray. And it is one that is worth talking about and, indeed, arguing over. My aim in writing this book is to help spur a healthy, informed dialogue about an energy supply that we still have much to learn about and that is changing the world we live in.

HYDROFRACKING

WHAT EVERYONE NEEDS TO KNOW®

This page intentionally left blank