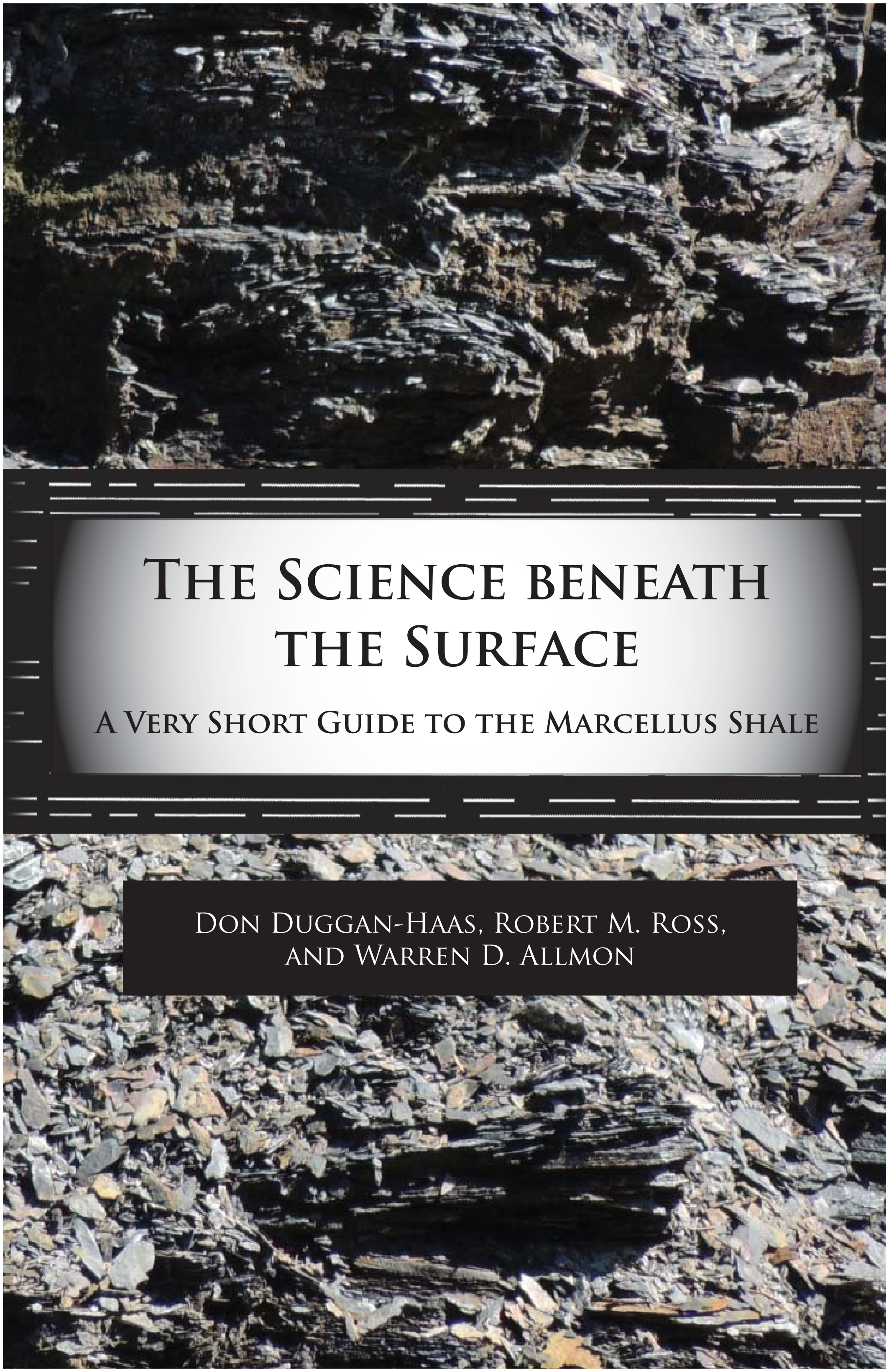
# The Science beneath the Surface

## A Very Short Guide to the Marcellus Shale



Don Duggan-Haas, Robert M. Ross,
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**On the cover:** Outcrop of the Marcellus Shale at its "type locality" (the first place that it was described in scientific literature, and for which it is named) in Marcellus, New York. Photo by Ben Aronson, courtesy of Linda Ivany.

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# Chapter 10

# So What?

As we stated in the Introduction, the purpose of this book is not to provide policy or regulatory recommendations about what decisions need to be made on high-volume hydraulic fracturing in the Marcellus Shale. Rather, our goal is to review and summarize in an accessible way, and in as impartial manner as we are able, the sort of scientific information and analysis that one might reasonably expect should be considered in making such decisions. Science isn't policy. It does not tell us what we should do. However, it should surely inform policy, and we should surely look to it for rational analysis of the possible consequences of what we choose to do. And science does—frequently but not always—reach conclusions that are recognized by a large enough proportion of knowledgeable experts to be codified as "what we know." The short summary below attempts to summarize the *current* state of what science "knows" (*i.e.*, has reached a reasonable consensus on) about natural gas in the Marcellus Shale. As discussed in the preceding chapters, there is ample reason to believe that many aspects of this tentative consensus might change in the near future as research proceeds.

The geologic history of the Marcellus Shale explains the occurrence and behavior of natural gas in the formation, and also informs many aspects of the processes of extracting that natural gas and the environmental concerns associated with that extraction. The Marcellus Shale was deposited approximately 390 million years ago in a warm, shallow sea with little bottom oxygen. Organic matter accumulated on the sea floor as microscopic organisms that lived near the surface of the water died and were buried without decomposing. Over time and with great heat and pressure, the organic matter was transformed into natural gas. Today, gas-bearing portions of the Marcellus Shale underlie parts of Pennsylvania, New York, West Virginia, and Ohio. The Marcellus contains a very large amount of recoverable natural gas.

The formation of the gas in the rock combined with tectonic activity to create natural fractures (joints) in the Marcellus Shale. These fractures increase the ability of gas to flow through an otherwise relatively impermeable rock. Artificial fracturing of the rock, however, increases the potential amount of gas that can be extracted. The process of fracturing the rock—by pumping large quantities of water, sand, and chemicals into drilled bore holes—is called high-volume, slickwater hydraulic fracturing (HVHF), or hydrofracking.

Natural gas has been known to exist in the Appalachian Basin (which includes New York and Pennsylvania) for hundreds of years. New York was home to the nation's first natural gas well, and has been producing gas commercially since the 19th century. Hydrofracking was developed in other shale gas basins, and has been used in its current form since the 1960s. What is new in recent years is the combination of hydrofracking with horizontal directional drilling, which was first used in the 1980s. The novelty of these combined technologies is the reason that natural gas drilling in the Marcellus Shale is referred to as "unconventional."

The purpose of hydrofracking is to increase the permeability of the shale to allow more natural gas to flow into the well bore and up to the surface. This is accomplished by fracturing the rock using a mixture of water and chemicals at high pressure to expand existing fractures and create new ones. Another material, usually sand, is then delivered to the fractures to keep them open so that natural gas can flow out of the shale.

Hydrofracking horizontal wells requires very large volumes of freshwater. The sourcing of this water, and its ultimate fate—both in the ground and after it is pumped back out of the wells—are major environmental challenges for large-scale, high-volume hydrofracking. Because of its geological history, the Marcellus Shale contains naturally occurring radioactive material, as well as high levels of salts, volatile organic compounds, and heavy metals. Some of these materials can threaten human health and the environment. Some of the chemicals added to the water pumped into hydrofracked wells are also potentially harmful to human health and the environment.

As with all large-scale energy development, negative effects to the environment are unavoidable in large-scale hydrofracking. There is no question that natural gas extraction (conventional and unconventional) can and has at least occasionally contaminated ground and surface water, although it can be difficult to prove that any single instance of contamination was a result of a particular gas well. Surface spills and leaks, faulty well construction, and erosion can all also contaminate local water supplies. Increases in certain air pollutants, such as volatile organic compounds and nitrogen oxides, both of which contribute to lower air quality, are also associated with Marcellus gas development, as the result of engines running drilling and hydrofracking equipment, truck traffic, and venting of natural gas in well-completion activities. Solid waste from drilling, much of it containing toxic materials, can leach chemicals into the ground if not properly disposed of. Soil erosion and habitat fragmentation caused by the build-up of drilling sites pose threats to both terrestrial and aquatic ecosystems and wildlife. Noise produced by drilling and fracturing activity has the potential to affect both wildlife and human populations in the areas near well pads and compressor stations.

Although current data suggest that hydrofracking itself does not cause significant seismic events (earthquakes), such events have resulted from disposal of drilling wastewater into the ground. The natural hydraulic fractures in the Marcellus Shale might or might not be likely to allow fluid or gas migration from the Marcellus Shale to major underwater sources of drinking water; it is highly unlikely, although possible, that fractures caused by hydrofracking allow additional large-scale migration and resulting contamination of drinking water.

All significant energy development has negative environmental consequences, and different forms of energy differ in the type and scale of consequences. Assuming that global energy needs stay constant or increase (which seems likely for the foreseeable future), the principal question for society is therefore one of choices. For example, from a global perspective, might the unavoidable negative consequences of natural gas extraction in the form of high-volume hydrofracturing (in the Marcellus and elsewhere) be "worth it," *if* the expanded use of natural gas (*e.g.*, at the expense of coal) could reasonably be expected to reduce the potentially much larger risks of global warming due to the buildup of greenhouse gases in the atmosphere and the array of other harmful effects of coal mining and use?

Unfortunately, despite a great deal of heated debate, there is currently no clear scientific consensus on the answer to this very important question. Emissions of methane ($CH_4$) from natural gas production and transport are significant sources of greenhouse gases (GHG) and so of global warming potential (GWP). Measuring $CH_4$ emissions from gas wells and other infrastructure is difficult and complex, and many more data are needed to reduce uncertainty in current estimates. Such studies have only recently begun. Although it remains unclear exactly how much $CH_4$ is emitted from natural gas development, all credible scientific studies agree that such emissions are serious contributors to global climate change and should be reduced as quickly as possible.

At least for now, the majority of studies appear to agree that GHG emissions associated with shale gas production are roughly the same as those for conventional gas production, and that natural gas in total has a lower potential future climate impact (PFCI) than coal over the 100-year time frame. This must, however, be seen as a tentative conclusion and, given the current rapid pace of research on this topic, will clearly be subject to increasingly rigorous tests in the months and years ahead.

The time frame over which GWP is measured sounds arcane, but is extremely important for understanding PFCI. Over 100+ years, carbon dioxide ($CO_2$) is clearly the most important influence on global climate. Focusing only on these longer time scales, however, obscures the potential importance of more abrupt changes—so-called "tipping points"—which might turn out to matter more for the future of Earth's climate than long-term GHG levels. The larger the effect of such tipping points are, and the sooner they might be reached, the more dangerous the shorter-term GWP of $CH_4$ becomes.

The current balance of scientific evidence suggests that replacing coal with natural gas in generating electricity currently could be a helpful "bridging" step toward slowing global climate change, but *only if it is a very short bridge* (*i.e.*, 20–30 years). If, however, cheaper natural gas makes even lower-carbon energy sources (such as wind or solar) less attractive, or encourages more fossil fuel use overall, then an increase in natural gas use could increase, rather than decrease, GHG emissions, accelerating rather than slowing global climate change. *In this case, there would appear to be little environmental justification for expanding use of natural gas, and the net scientific judgment of overall risk would likely be that the risks of large-scale hydrofracking outweigh the benefits.*

Throughout human history, changes in our overall energy sources and uses have changed both slowly and very rapidly. These changes—and their consequences—have usually been unforeseen and in retrospect would have been difficult or impossible to predict. Frequently, one part of the system changes gradually while another is quickly transformed. For example, almost all of the nuclear power plants in the U.S. were built in the course of 20 years, and almost all of the wind generated electrical capacity in the world has come online in the last few years. Our transportation system moved from domination by animal power to coal to petroleum over a century, but in steps that each took only a few decades, each occurring after a new technology appeared and showed a clear advantage.

In the present, much more crowded, connected, and faster-changing world, there is widespread need for better forecasting and planning of our energy future, rather than just "letting it happen." If, as many scientists suggest, the already degraded global environment is rapidly approaching multiple tipping points, past which dangerous or even catastrophic environmental changes cannot be avoided, then the stakes for more accurate projections are even higher.

Such predictions remain extremely difficult, however, because energy choices are not just about science and engineering, but also about politics, economics, and society at local, regional, and global scales. This complexity, and the uncertainty that it creates, is not an excuse for inaction, but *must* be recognized if any lasting progress is to be achieved. HVHF in the Marcellus Shale has caused, and will continue to cause, environmental damage. Most of this damage has so far been limited to local or regional scales. The longer-term effects of present and future gas development in the Marcellus, or any other gas shale deposit, however, will depend less on what happens in New York or Pennsylvania than on decisions about national and global energy use and development.

Real and substantial environmental and other risks are associated with large-scale hydraulic fracturing in the Marcellus Shale. Deciding whether these risks are lesser or greater than the risks associated with other energy choices is not just a question about the Marcellus. Successful risk management involves diminishing existing risk, preventing future risk, evaluating benefits, assessing cumulative impacts over decades, and making economic, social, and ethical decisions, none of which can be made with total certainty.

For New York State in particular, where development of the Marcellus has not (at the time of this writing) started and in which it has been so controversial, substantial risks associated with the regional energy system are borne by people, ecosystems, and economies outside of New York State. Although New York residents and businesses get almost twice as much energy from natural gas than any other source, only a tiny amount of the gas used within the state comes from gas wells within the state.

Transitioning from one energy source to another has almost always meant transitioning from one set of risks and benefits to another. The fundamentally different nature of different energy sources makes comparisons of risks challenging. Because all large-scale energy production methods have substantial risks, the most direct—although not necessarily the simplest or least expensive—approach to lowering risks to public health, ecosystems, economies, and communities is to use less energy.