ENHANCE OIL & GAS EXPLORATION

WITH DATA-DRIVEN GEOPHYSICAL AND PETROPHYSICAL MODELS

KEITH R. HOLDAWAY
DUNCAN H. B. IRVING

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Enhance Oil & Gas Exploration with Data-Driven Geophysical and Petrophysical Models

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Keith Holdaway: To my patient and loving family, Patricia, my wife, and my children, Elyse and Ian.

Duncan Irving: To Sarah, my wife, and my children, Alfred, Edwin, and Ingrid, who have had to put up with less daddy-time than normal during this creation. Sorry, and thank you!

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Foreword

I vividly remember the first time I met Keith Holdaway. It was 14 years ago, and he was standing in the front row of an analytics conference. He cut a distinctive profile as he challenged the speaker at the podium, asserting quite stubbornly that the oil and gas industry could realize huge returns by using a more data-driven approach that exploited the full potential of analytics. As a young man (or so I thought of myself at the time), I had been tasked with selling analytical software to upstream oil and gas companies. Coming from a technology background, I realized that this gentleman was the guide I was looking for and made a mental note to seek him out at the cocktail hour.

Back then, in 1989, the digital oilfield was the topic of the day, promising impressive returns. As the industry embraced the concept more fully over the next decade, I observed companies making significant investments in specific data solutions to automate and solve a broad range of problems. Thought leaders eagerly embraced the application of data-driven analytics, but the adoption was not necessarily as widespread as one would have thought. Scattershot adoption created its issues, with companies sometimes running hundreds of disparate applications and ending up with silos of data across their organizations. The promise remained.

Fast forward to 2014 and Keith's first book, *Harness Oil and Gas Big Data with Analytics*, which arrived just before crude plunged to historic lows. In retrospect his book seems almost prescient as the industry's enthusiasm for data-driven analytics has been driven in part by the potential to generate greater value from its assets in the face of a much lower price per barrel. Many of the leading players—and several influential thought leaders among smaller oil companies—have made substantial investments in this area, and there is more to come.

Increasingly, I am contacted by clients looking for data scientists, asking for training, and seeking guidance on how best to implement advanced analytics programs. We often point them to Keith's book, among other resources at SAS and elsewhere, to help them validate the best path forward.

Hence the genesis of this new book. Interest in his first book has been consistent enough that colleagues implored Keith to write a second volume: a more particular text that digs deeper into applying data-driven approaches across the exploration sector. Keith and his colleague, Dr. Duncan Irving, have written an invaluable book, exploring the data-driven methodologies in the disciplines of geophysics and petrophysics. And the timing is right. We are witnessing an unprecedented convergence of big data and cloud technology with massive increases in computing power at a time when a climate of low prices has made driving efficiencies an absolute requirement. Add to that the influx of technology-attuned Millennials into the workforce, and oil and gas practitioners are on the verge of a new era of opportunity to transform their business.

I have no doubt that this volume will be a valuable addition to the growing body of resources focused on this exciting area. Over years of working at the nexus of energy and technology, Keith has become a mentor and friend. His colleague is a globally recognized geophysicist working in the field of data analytics and brings innovative ideas to the evolving science of data-driven and soft-computing technologies. This new and important book is the result of years of deep work in this area and a real passion for the topic, approached with the same determination I saw at the front of that conference room many years ago. I am honored to introduce this book: *Enhance Oil & Gas Exploration with Data-Driven Geophysical and Petrophysical Models*.

Ross Graham,
Director, O&G Americas
Calgary, June 2017

Foreword

The oilfield is one of the most data-rich industries in the world, and concerning real information (as opposed to virtual data generated by the web and other virtual environments) can lay claim to the most data intensive industry. Most organizations, if they are honest with themselves, rarely capitalize on the potential of analytics and 'big data.' The authors of this book address the most common pitfalls that beset analytics and provide a comprehensive framework and roadmap, from the exploration and production perspective, to achieve the real goal of analytics—simplifying, expediting, or making possible the translation of data into profitable and sustainable outcomes.

To unleash the power of analytics, one must first understand what they are and are not. Analytics are data-centric processes that, if designed and executed properly, will lead to insights and outcomes. Each aspect of the process must receive due diligence, and the focus of the endeavor should always be to add value to the organization.

WHAT ANALYTICS IS NOT

The most common mistake when understanding analytics is to confuse the sizzle with the steak—that is to conflate the perception of a thing with the substance of the thing. Many managers and even technical professionals accept the misconception that analytics is the collation and visualization of data using colorful charts and graphs. This is not only incorrect, but there is a tacit danger in this assumption because it can significantly limit future analytic endeavors that do not, per se, yield an attractive visual. It must be understood, therefore, that dashboards and

reports are one of many results of analytics and, while they are the most visible, they may not be the most valuable.

WHAT ANALYTICS ARE

Analytics are multi-step processes which transform data from one or more sources into information which leads to changes in actions and behaviors; and, if an organization is unwilling to do either, investment in analytics should be reconsidered. This book, more than any other before it, details a simple, yet robust, approach to developing an analytics plan that will lead to success. Though analytics methodologies vary depending on query most processes should contain at least the following:

- Data Modeling. Analytics planning should ensure, within practical limits, that necessary and sufficient data are identified beforehand.
- Data Gathering with a focus on quality. Identification and management of adverse data are often far more resource intensive and problematic than data that is missing. Acquiring real data often involves rigorous technical and contract specifications that include detailed definitions of data properties.
- Data Management—how data will be transferred, stored, secured, transformed, and distributed.
- Analysis—Understanding which analytical methods are most appropriate based on types of data and questions asked as well as the speed and accuracy of the desired results.
- Communication—Determining the most efficient and influential modes in which to communicate data to those who should, or could, consume it—whether it is formal reports, presentations, email, social media, audiovisual, or combination of these and other forms.

- Management of Change. Perhaps the most important, yet sadly overlooked, part of an analytics project involves: identifying, before work begins, who all relevant stakeholder (or customers) are, clearly documenting their needs, and agreeing in advance on if, or how, changes to process might occur based on the results of analyses.

Nathan Zenero
President,
Verion Applied Technologies

Preface

Our motivation for writing this book comes from the professional curiosity and experience we have accumulated over recent years in the Oil and Gas industry. We have noted and continue to witness the struggles between geoscientists and their multiple spatial and temporal datasets. Traditional interpretation can provide certain answers based on Newtonian physics and the fundamental laws of nature, but with so much data being amassed with sensors in this digital age, it is necessary to marry deterministic interpretation with data-driven workflows and soft-computing models.

Owing to the cyclical nature of the Oil and Gas industry, we have seen historically depressed crude prices since 2015. This last downturn, like previous historical downturns, shook the industry to the point of an overreaction: people losing their livelihoods, reduction in OPEX, and cancellation of projects, particularly in exploration. It is at these transition points that oil and gas companies seek more efficient work processes and best practices. This invariably results in the adoption of technologies not necessarily new in other industries. Today we see more adoption of soft-computing and data-driven analytics to complement the traditional interpretation.

Given these cyclical-downturn scenarios, we ask ourselves, being in the trough of a current downturn: What's happening in the Oil and Gas industry today?

We are aware of the dramatic drop in crude oil prices that is a driver behind the industry's march toward adopting new technologies such as analytical and soft-computing workflows. Oil and gas companies realize the climb from the bottom of the cycle is a slow process and has many global and local influences. Too much supply and weak global demand play into a dynamic scenario.

Oil and gas companies are currently contemplating serious near-term investments to develop global assets, but it behooves the industry to move gingerly. We shall witness an inexorably slow increase in oil prices, with global supply bound by the reduction in reserve development projects over the past few years.

Many talented engineers have left the industry, and the internal organizational vagaries, coupled with inflexible and complex systems, processes, and attitudes could put the breaks on any innovative and evolving methodologies and best practices. IOCs and NOCs are looking seriously at a digitization environment using advanced analytics for the new daily workflows. Service companies, analytics vendors, and in-house capabilities are emerging to address these needs. This will enable oil and gas companies to weather current and future industry downturns.

We see this book as a contribution to enabling upstream geoscientists in data-driven analytics in geophysics and petrophysics. We hope it serves to bring together the practitioners of conventional upstream computing workflows with the new breed of data scientist and analyst and generate overlap and common ground so they can understand each other's perspectives, approaches, and role in this new computing landscape.

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CHAPTER 1

Introduction to Data-Driven Concepts

"Habit is habit and not to be flung out of the window by any man, but coaxed downstairs a step at a time."

Mark Twain

INTRODUCTION

Current Approaches

We wish to air some of the more important practical considerations around making data available for data-driven usage. This could be for static, offline studies or for operationalized, online reviews. We introduce the concept of data engineering—how to engineer data for fit-for-purpose use outside the domain applications—and we take the reader from the first baby steps in getting started through to thoughts on highly operationalized data analysis.

A geoscience team will use an extensive collection of methods, tools, and datasets to achieve scientific understanding. The diversity of data spans voluminous pre-stack seismic to single-point measurements of a rock lithology in an outcrop. Modeling approaches are constrained by:

- Size and scarcity of data
- Computational complexity
- Time available to achieve a "good enough" solution
- Cloud computing
- Budget
- Workflow lubrication

It is this last constraint that has proven the largest inhibitor to the emergence of a data-driven approach in exploration and production (E&P). It is a motif for the ease with which data and insight are moved from one piece of software to another.

These constraints have led to a brittle digital infrastructure. This is problematic not only in the individual geoscientific silos