INTRODUCTION: 2016 M-OSRP Annual Report

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The basic function of this Report is to describe and document the progress our group has made and delivered this past year.

This Report documents the projects, goals, strategies, methods, progress and plans.

We begin by providing a perspective, context and framework for this Annual Report. Within that perspective we will raise and respond to several important questions, that help define the underlying cause of seismic exploration challenges and the unique, effective and impactful M-OSRP strategy and response.

M-OSRP's objective is "to identify and address the most significant, pressing and prioritized seismic E&P challenges".

Why are there challenges? How do you know there are challenges? What are the M-OSRP approaches to identifying and addressing challenges? How does the M-OSRP approach to, and strategy for, addressing pressing and prioritized challenges distinguish itself and provide relevant and differential added value- and ROI compared to all other consortia, and all other seismic research groups in the world?

SEISMIC CHALLENGES: WHAT CAUSES THEM?, THE DISCONNECT TODAY BETWEEN SEISMIC PROCESSING AND THE DRILLING SUCCESS RATE, and the M-OSRP RESPONSE

All seismic methods make assumptions and have prerequisites and requirements. When those assumptions, prerequisites and requirements are satisfied, the methods are successful, and effective. When they are not satisfied the methods will be less than effective or can fail. The latter breakdown or failure of seismic processing effectiveness is what contributes to and in fact defines seismic challenges. That breakdown in seismic effectiveness directly contributes to and results in dry hole exploration drilling and sub-optimal development well placement.

How do we know there are seismic processing challenges? The clearest way to know that challenges exist is to look at the exploration and development drilling success rate, (US Department of the Interior, Mineral Management Services) in e.g., the one in ten success rate for frontier exploration well drilling in the deep water Gulf of Mexico. That success rate basically hasn't changed in 25 years.

That reality means that there are major shortcomings in our seismic processing capability. That means there is much about our collective seismic capability that is not working, and certainly not working often enough and well enough. That in turn means that we need to take a hard look at our seismic methods to understand what's behind the failures. And to have a clear understanding that if we have an interest in any positive change, let alone a significant positive impact, on improving that drilling success rate it will require a new level of seismic capability, requiring fundamental new visions, concepts and methods beyond our collective capability today.

IGNORING THE DISCONNECT

There are many who would prefer to ignore that drill success rate and seismic technical capability relationship and reality. They circle the wagons, close ranks, and insist that their methods are actually working, and that all that is needed are cosmetic changes and more attention to data acquisition and HPC.

That's what we call the seismic disconnect and gap.

ADDRESSING THE DISCONNECT

M-OSRP is all about recognizing and addressing that disconnect and gap. It is easier to go along with the mainstream orthodox and conventional view and approaches than to ask the uncomfortable, difficult, right and essential questions and to actually define what is behind a lack of seismic effectiveness and commensurate dry hole drilling.

The M-OSRP logo of 'solve the right problem' might sound like pap. It isn't.

M-OSRP and the SEISMIC PROCESSING CHAIN

The projects within our program address major prioritized and pressing challenges, addressing open issues that provide solutions on every link in the seismic processing chain. There is no link on the processing chain that is 'not our business'. Every earlier link and prerequisite on the seismic processing chain that precedes a particular method that we are progressing is our business and our responsibility. That ownership and comprehensive view of seismic processing is reflected in the breadth and scope of our projects, and the depth of analysis within each project in our program and in this Annual Report.

ADDRESSING THE CHALLENGES

Among assumptions behind seismic processing methods are :

(1) The fundamental assumptions and physics assumed, and concepts and theories called upon, in deriving the algorithm

(2) Data acquisition requirements

(3) Prerequisites, seismic processes that must precede a given algorithm and step or link in the processing chain

(4) The need for subsurface information

What if a basic underlying assumption or concept behind an algorithm, or a prerequisite or subsurface information is not satisfied, are lacking and inadequate- and that is contributing to seismic difficulty and failure?

There are two different types of responses to the violation of the assumptions behind a seismic processing method and algorithm.

(1) Develop approaches, methods that provide more effective delivery of assumptions, for example, data acquisition, prerequisites, and e.g., necessary subsurface information;

(2) Develop methods that don't require the assumptions and requirements that are difficult to satisfy.

We adopt one or another of these responses for the challenges we address- and M-OSRP addresses challenges in every link of the seismic processing chain. The projects within the program that are providing preprocessing steps like separately predicting the reference wave-field (and ground roll) and reflection data, without injuring either, and de-ghosting for both towed streamer marine, and on-shore and OBC plays, are examples of high-grading the ability to satisfy assumptions and requirements that we don't know how to avoid. The projects like: (1) internal multiple elimination and (2) the first migration that will be equally effective at all frequencies at the target and reservoir , place a very high bar on those prerequisites being satisfied. That explains the resource allocation, and the time and effort on those prerequisite projects within the Annual Report and at the Technical Review.

WHAT MAKES M-OSRP UNIQUE AND AN OUTSTANDING ROI?

There are several factors that make M-OSRP unique. One is the fundamental and basic starting point in examining any problem,

with no method, approach or viewpoint being sacrosanct, and immune from scrutiny. And where extra special scrutiny is reserved for those methods and approaches that we pioneered, developed and delivered.

MIGRATION

For example, if we progress current migration theory and application, we don't start with some favorite commonly used RTM formula , but rather we start at the beginning with the math and physics behind imaging principles, for underlying assumptions , and not avoiding those real issues by rushing , e.g., to extremely important but less fundamental and more comfortable HPC concerns. A new and first more capable migration method that is equally effective at all recorded frequencies at the target and at the reservoir is presented in this report. The benefits are improved structural resolution and amplitude analysis, in comparison to all current leading edge migration methods.

MULTIPLES

Below we discuss another example of the importance of your starting point when examining a method or approach for addressing a seismic challenge and problem.

SEISMIC PROCESSING : THE NECESSARY DISTINCTION BETWEEN MODELING AND INVERSION

Seismic processing is an inverse problem. There is a widespread, growing and deep misunderstanding and confusion concerning what (seismic) inversion is actually all about. Seismic inversion is completely, totally and utterly different from modeling and model matching. Often model matching is mistakenly and unquestionably assumed as the very definition and starting point for 'inversion'.

We share here one among innumerable examples that point out what's wrong with that mistaken and misguided view of 'inversion' . The inverse scattering series(ISS) is a direct inverse method, and the ISS internal multiple algorithm, not only doesn't require sub-surface information to predict internal multiples it is completely earth model type independent. Model type independent means it is exactly the same unchanged algorithm(not a single line of code changes) for an acoustic, elastic, heterogeneous , anisotropic and inelastic, absorptive dispersive earth . Model type independent modeling? It's direct inversion multiple removal and not modeling and subtracting the multiple. That ISS internal multiple algorithm can predict converted wave internal multiples (e.g. P-S-S-P) with an acoustic water speed reference , a reference medium where an S wave cannot exist let alone propagate. Clearly the ISS internal multiple algorithm could not possibly be modelling that multiple. Again, inversion is not modeling or model matching.

And there are those who say they fully and completely understand how internal multiples can be attenuated from a subseries of ISS but they firmly believe and completely understand that internal multiples cannot be eliminated from the ISS. In fact they really don't understand either one. Their confusion resides in not understanding the difference between modeling and direct inversion.

This report provides the first internal multiple elimination method for a multi-dimensional subsurface derived from the inverse scattering series. As expected it is direct and doesn't require or need subsurface information. Not only is there no need for actual subsurface properties, the reference velocity in the algorithm can be chosen arbitrarily and need not correspond to water velocity for marine cases or near surface properties for on-shore application. No velocity or subsurface information is called for, none whatsoever. In the Report examples of ISS internal multiple

elimination are shown eliminating a converted wave internal multiple, with a water speed acoustic reference.

HIGH M-OSRP SEISMIC EFFECTIVENESS AND HIGH COMPUTE DEMAND

The methods that M-OSRP has delivered for addressing multiple removal, are recognized as having stand-alone capability and effectiveness- as the only methods that do not require subsurface information. They are also extremely compute demanding, and the next delivery of internal multiple elimination will bring along with the next level of effectiveness a commensurate yet higher compute requirement. Separately, the new Stolt extended Claerbout III imaging for heterogeneous media, that M-OSRP is developing, is more effective than all current migration methods, and will also have its own high compute demand. How to take advantage, to deliver and apply this next level of seismic effectiveness in a cost and capital reduced environment?

MATCHING WHAT TO COMPUTE AND HOW TO COMPUTE IN A CAPITAL AND COST REDUCED ENVIRONMENT

This year at the 2016 M-OSRP Annual Technical Review and Meeting on June 8, 9th we will describe a proposal and plan from IBM for delivering that capability in a cost-effective reduced capital expenditure environment.

SUMMARY

This Introduction provides a view of our approach to defining and addressing seismic challenges, and a sampling of progress within M-OSRP projects. Progress and plans for all projects are fully documented and reported in this Report and will be presented at the Annual Technical Review on June 8, 9th, 2016.

This has been another outstanding year for our group, and we are deeply grateful for your encouragement and support.

Warmest best regards,

Arthur B. Weglein

May 31, 2016