Seismic Based Rock Properties Predictions for Site Specific Well Planning & Real Time Operations – A Subsalt Case

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Abstract

Planning Drilling Operations has historically and predominantly relied upon offset well data to act as a guide for future well plans. The need for site specific, seismic based, rock properties predictions (lithologies, porosities, overburden gradients, pore pressure, fracture pressures, fluid types, and seal integrity) has always existed but until recently has not been available.

In 2001, Pioneer Natural Resources Deepwater (DW) Drilling /Completion Department sought out and have very successfully used commercially available pre-drill, seismic based, rock properties prediction services on seven PNR operated DW exploration wells and several partner exploration operated wells. As a result of using this emerging technology, PNR DW GOM wells' have to date not had a well control event, have been able to secure regulatory approval to eliminate a csg strings normally required on the first well in OCS blocks, and successfully predicted six out of seven times whether a significant gas column was present. On a recent partner operated DW well this prediction technique used a patented, seismic frequency based, pore pressure technique that successfully predicted subsalt pore pressures where velocity based techniques could not due to a lack of usable data below the salt.

Also, this technology is also used during real time drilling operations to constantly predict, compare, recalibrate, and repredict the undrill rock properties. When using this process, the risk of inaccurate predrill predictions is reduced as compared to using offset wells where the risk actually increases if non similar to offset geologic or pore pressure environments are encountered.

An additional benefit of using this process is the creation of a data framework that required and fosters interdisciplinary interactions.

Introduction

The basis of any prospect is the rock and the goal of the project team is to accurately describe that rock. Due to location to location variations in the subsurface environment, site specific subsurface rock properties predictions are required not only for prospect generation but also for subsurface operations. As the G&G members of the interdiscipline team use the site specific, seismic based data, so should the team members from the Drilling / Completion group. This requires a culture /workflow change for engineers, as the use of the seismic based data requires involvement early-on in the prospect generation process to insure that the data is acquired and processed so that all disciplines can effectively use the data for their portion of the project.

Rock Properties Predictions
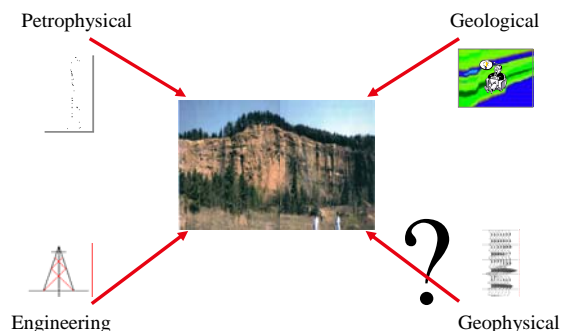
In any project, data use is most efficient if the members of the interdisciplinary team have a common data set and that data is presented in simplified teaming documents.

Life Cycle Analysis

Four years ago, Pioneer's DW Drlg Group started using teaming documents in the form of an interdisciplinary Life Cycle Analysis (LCA) business plan/data checklist and a seismic based processing technique that generates 3D cubes of various predicted rock properties. This early use of the process and the results of the Pioneer first DW well were discussed in IADC/SPE 74487.

Life Cycle Analysis

ITEM	DATA
Meteorological / Oceanographic Affects	Hurricane Season (June - Nov); Loop Currents (Dec - Oct); Chemosynthetics (J Landreth, J Hall)
Expendable / Producer (Suspend, Complete)	Suspended as a producer after discovery
Flowline to (Semi, TLP, SPAR, P/F, FPSO)	Flowline to Spar (J Hall)
Product Export Facility (Pipeline, Tanker)	Pipeline (J Hall)
Location & Type of tree (Subsea / Surface)	Subsea Horizontal (B Gray, M Drew, J Landreth, J Hall)
Template or Indep. Prod. Guidebase	Independent Well Production Guidebase
Orientation of Guidebase/Tree	Layout Dependent (J Hall)
Horizontal Distance to Prod Facility	47(35) miles
Production: Oil / Gas / Injector (Water/Gas)	Gas (B Gray, M Drew)
Production Flow Rates Hydrocarbons : Max / Min / Avg / Life Expectancy Condensate : Max / Min / Avg / Life Expectancy Water : Not Expected Non Hydrocarbon-Max / Min / Avg / Life Expectancy	220 / 100 / 180 MMcfpd / 8 yrs 2200 / 1000 / 1800 BCPD / 8 yrs NA 1.8MMcfpd (B Gray)
Vertical, Directional, Horiz, or Multi-Lateral	VERTICAL Wellbore (B Gray, J Landreth)
Sour Gas (H_2S, CO_2) **; Alloyed Tubulars**	CO_2 (9 -13 Cr) (B Gray)
Sand Control /Stimulation Requirements	GRAVEL PACK (B Gray, K Doud, J Landreth, M Drew, D Williams)
Single / Selective / Dual / ESP / Gas Lift	1 Single Selective / 2 Singles (B Gray, J Landreth)
Flow Assurance (Wax, Paraffin, Asphaltenes, Hydrates)	Hydrates (B Gray, M Drew, J Hall, J Landreth, D Williams)
Corrosion / Flow Assurance Inhibition	Corrosion (CO_2) & Methanol (Hydrates)
Tbg(s) Size(s) / Prod/Tieback Csg Size(s)	$5-1/2$" / $10-3/4$"
SCSSSV:OD / ft BML / WP, **OD:Cables & Lines**	8.26" / +2000'BML / 10K psi WP / N_2 Charge; 2($1/4$" hyd lines);Opening Pressure 2,500 psi (assume 5000 psi > BHP) ; Min ID= 4.562"

Site specific seismic based predictions are used to quantify and qualify inputs into the LCA. To generate this data about the rocks from seismic or visa versa one must use a process as shown below.

Seismic to Rock Properties

Lithology? Porosity? Fluids?

Predictions of rock properties from seismic have been a challenge since of the advent of seimic. Various techniques and processes have been tried and used over the time but 5 years ago new techniques were developed named LithSeis and DrilSeis. The basis of the techniques is rock-based integration which is defined

as the geologic interpretation of the results generated by the integration of seismic and petrophysical data. The mathematical keys to the above mentioned integration of the geoscience data is inverse and forward modeling.

eScis
Inversion vs Forward Modeling

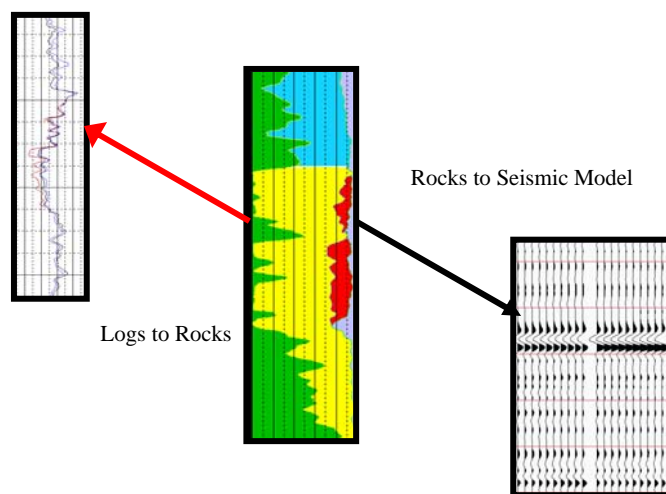Well Logs — Rocks, Fluids / Logs / Synthetic

Post Stack Seismic — Rocks, Fluids / Impedance / Seismic
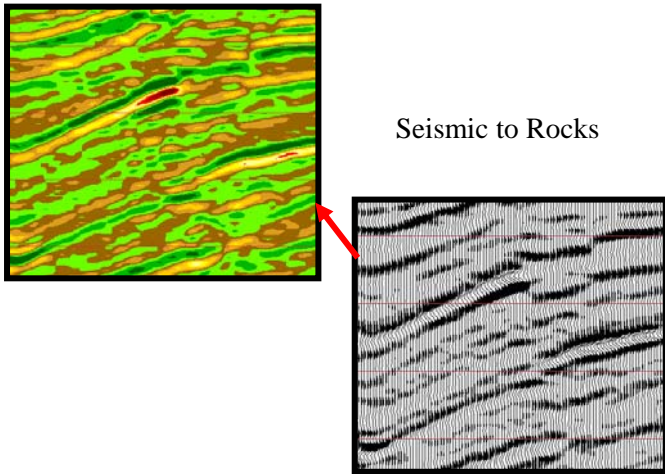
Pre-Stack Seismic — Rocks, Fluids / P & S Impedances / CDP Gathers

Forward Modeling ⟶
Inverse Modeling ⟵

Logs to Rocks

Rocks to Seismic Model

Seismic to Rocks

Migrated Stack

Using seismic petrophysics (data generated by AVO calculations and by using techniques similar to log analysis cross plotting) the seismic data is inversed modeled to generate rock properties predictions.

The significance of the above steps (LithSeis) is that lithology, fluids, and porosity have a significant impact on the prediction of velocity based pore pressure predictions.
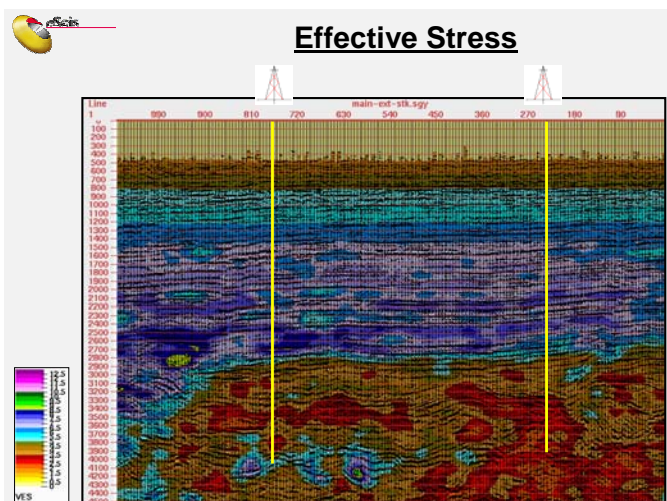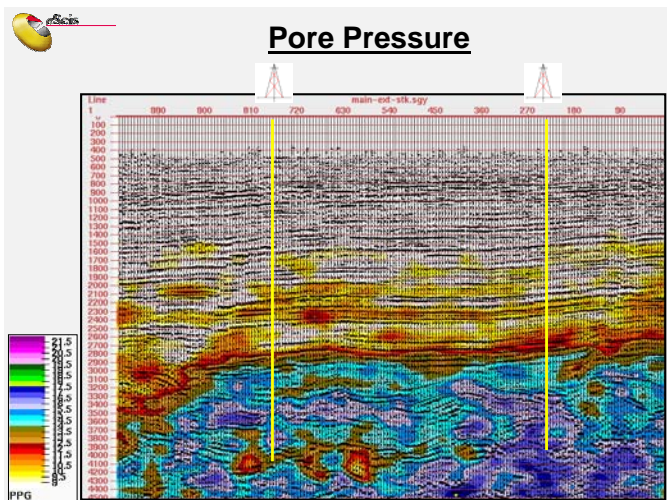
LithSeis

Inversion

AVO Gradient

Lithology/fluids

Porosity

Shale
Dirty Sand
Wet Sand
Gas Sand
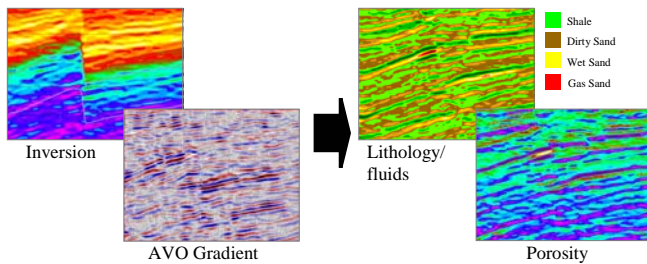
Combining inversion, AVO and petrophysical technologies yields lithology/fluid and porosity sections.

Lithology, Porosity, Fluids
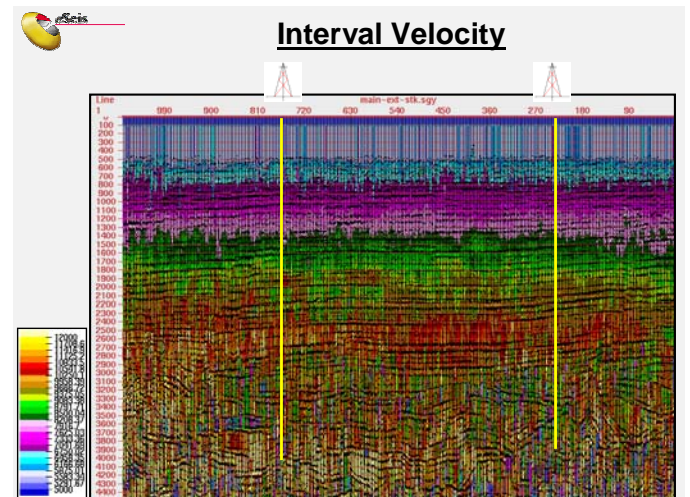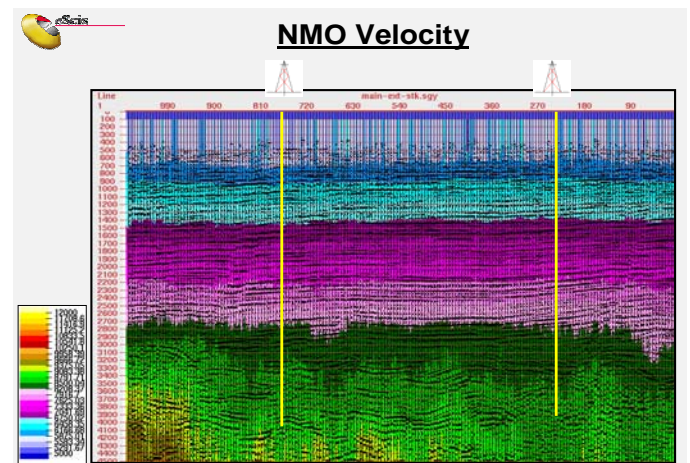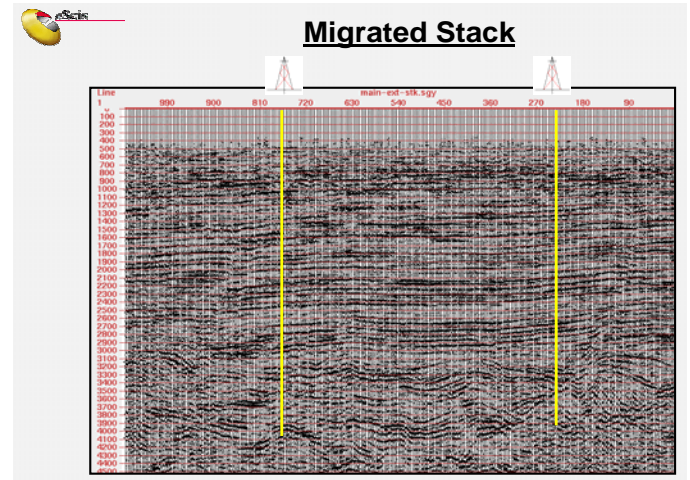
NMO Velocity
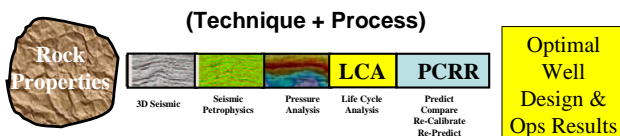
OBG, PP, FG, Centroid, Seal Intergrity

With seismic generated velocity and frequency, pore pressures can be predicted that take into account the other rock properties. The following demonstrate the importance of all the rock properties being considered when predicting pore pressures, fracture gradient, seal integrity, and fluid column height.


Interval Velocity

Pore Pressure

Effective Stress

These techniques (LithSeis, Dril Seis, & PCRR) were used on the subsalt well displayed below and due to the use of the patented frequency based pore pressure predictions technique the well was successfully drilled subsalt w/o having to set another string of pipe despite the lost returns encountered below the salt. Instead using PCRR, the partnership was able to cut the MW by .5-.8 ppg and drill to the next csg point as the recalibration process confirmed that the predrill prediction was accurate.
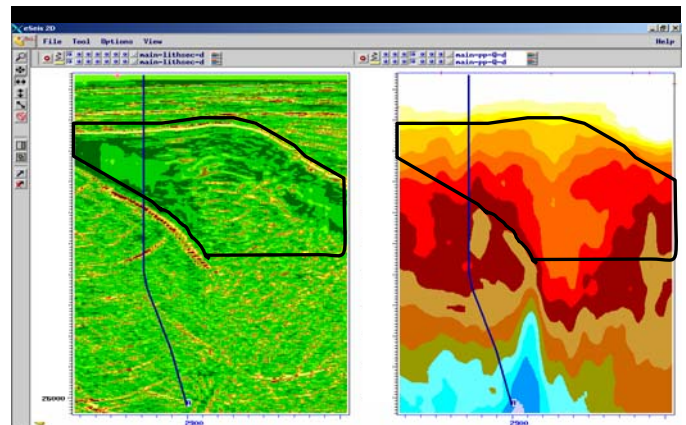
Conclusions

1. Life Cycle Analysis provides Drilling Engineers a tool by which project data can be managed so as to insure that the well is designed for all team members operational and the company's financial needs.
2. Seismic based rock properties predictions tools provide Drilling Engineers' site specific, user friendly, readlily interpretable, seimic based data that can be used in interdisciplinary team discussions.
3. Continuing use and development of this specific technology has resulted in a stream of continual improvements.
4. PCRR is a technique which generates real time quality and quantification of predrill and currently be drilled rock properties predictions.

Acknowledgements

With the rock properties an engineer can plan the well with a predicted predrill mudlog and pressure plot. The process below defines the steps of the well planning and drilling ops process and includes the real-time step technique that is used to guide the drilling from spud to TD.

Real Time PCRR

Predict, Compare, Recalibrate, and Repredict (PCRR) are the steps used in realtime ops that insure that a continual update is being generated as each 50' to 100' is drilled.