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Rock Physics Integration: From Petrophysics to Simulation

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Summary

This paper will discuss about the role of rock physics in reservoir characterization and how it can act as an integrating tool with and between Petrophysics, Seismic, Geomechanics and Simulation. The application of rock physics in each discipline will be discussed very briefly and the importance of having rock physics as an integrating tool will be discussed.

Keywords: *Rock Physics, Reservoir Characterization*

Introduction

The science of rock physics creates a bridge between elastic properties (e.g. Vs/Vp, seismic, elastic moduli etc.), reservoir properties (e.g. porosity, saturation, pressure etc.) and reservoir architecture (e.g. laminations, fractures etc.) properties. It also should allow for a reliable prediction and perturbation of seismic response with changes in reservoir conditions. An appropriate rock physics model should be consistent with the available well and core data, surface and borehole seismic as well as production and reservoir engineering figures. This requires that rock physics act as an integrating tool between different disciplines or as being described by Schön (1996) 'Rock physics is integrated into the general techniques, strategies, algorithms, and the complete process of exploration, and simultaneously is an integrating part of this process, because rock physics couples and connects the different disciplines'. Therefore, rock physicist should seek to establish such relationships between the reservoir properties and observed elastic responses measured at the surface of the earth, within the borehole environments or even in the laboratory. This relationship should be a predictive theory so that reservoir properties can be detected seismically.

Creation of a rock physics model normally initiated from petrophysics study, when the measured logs and cores are available to formalize subsurface elastic behaviour. Then, this model should be updated and improved using geology information and measured seismic as well as production data within the cycle of reservoir life. Furthermore, this rock physics model which should be consistent with all of the available reservoir information can be used in many different applications and workflows, such as:

- Seismic reservoir characterisation,
- Anisotropy analysis,
- 4D feasibility and modelling,
- AVO and AVOZ analysis,
- log modelling, calibration and generation,
- Fluid substitution,
- Pressure prediction,
- Geomechanical studies,
- Fracture detection, orientation, and mapping,
- Velocity studies and forward modelling.

Here, I will quickly discuss rock physics application within different disciplines in the reservoir characterization process and highlight its role as an integrating tool.

Rock Physics and Petrophysics

Petrophysics focuses on interpreting logs for formation evaluation, while rock physics focuses on understanding the relations between geophysical measurements and rock properties. Traditionally, the two disciplines were approached as separate activities since the petrophysicist and rock physicist each developing distinct models and setting distinct control parameters. However, the integration approach for imaging subsurface requires a strong link between these two disciplines as well. Therefore, petrophysicist should provide primarily input (e.g. clay volume, porosity, Sw) and rock physicist should use them to build and calibrate a valid rock physics model. The input parameters are constantly updated by synchronizing the model and control parameters between two disciplines through several iterations. The output of this iteration is a calibrated rock physics model and parameters which represent elastic properties changes due to the lithology, fluid, pressure etc. changes at well location. This model represents a relationship which is valid at the well location, and should be calibrated with other information like seismic if we wish to use it in a broader aspect. However, geological information (surface geology, geochemistry etc.) can also be considered as the global or local trend in the rock physics model and make the model more general.

Rock Physics and Seismic

Reflection seismic helps with creating with 2D or 3D image of the reservoir by providing the subsurface seismic properties. These properties can be used to construct structural frame of the subsurface using different attributes. Further information can be extracted applying different seismic characterization methods such as Amplitude Versus Offset (AVO), inversion etc. However, all of these methods provide an image within elastic properties domain, and a rock physics model is needed to convert them into reservoir properties which are more familiar for the geoscientist and engineers. The calibrated rock physics model from petrophysics should be used and updated for this purpose. The procedure normally starts from the well tie analysis where well data are used to create a synthetic seismic which should be tied with the measured seismic at the well location. In addition to the wavelet and rock physics parameters, input from petrophysics (e.g. clay volume, porosity, Sw) also should be considered for updating. Furthermore, this model can be used for velocity modelling, AVO analysis and finally for inversion study. The input and parameters for the rock physics model are considered as dynamic, and they should be updated at any stage if any inconsistency is observed. The important issue for building such a solid rock physics model is to consider consistency between all disciplines within such an iterative approach. This means that parameters or input updates at each step should not violate the measured data at other steps.

Rock Physics and Geomachanics

The complex geological history of earth makes it as a stressful place. This stress regime influence reservoir studies and drilling operations. Furthermore, drilling a borehole and producing hydrocarbon from it make this stress regime even more complex. Drilling and production activities alter the local stresses and pore-pressure regimes near the well trajectory. These local changes may have advantage or disadvantage for operations within the cycle of the reservoir life depends on how we plan and model them. Wellbore collapse and failure, sand production and fracturing are some examples for stress effects on reservoir level which could be managed with a proper study in advance. Two elastic constants named as Young's modulus and Poisson's ratio can make a solid link between elastic and geomechanical properties of a reservoir. The rock physics relationship calibrated with well and seismic data in theory should represent the subsurface engineering properties, and should give user the ability to model and predict stress field at different locations. However, this link is not well developed and studied like the Rock Physics and Petrophysics link, and still needs more research and study.

Rock Physics and Simulation

Reservoir simulation main goal is to predict fluids flow within porous media, and having an accurate static model can help with building a well predictive dynamic model. These subsurface static models are based on physical measurements and as a results rock physics models are needed as the core of the static modelling. Furthermore, new advances in seismic characterization make it possible to model dynamic properties from elastic properties. These new technologies are dependent even more on rock physics and need more accurate models. 4D seismic is now integrating more and more with reservoir engineer to monitor subsurface fluid flow within their EOR process. Furthermore, Seismic-To-Simulation and Simulation-To-Seismic are two advance processes which deal with making an accurate dynamic model in addition to a correct static model. The core of all of these processes is establishing a valid relationship between dynamic reservoir properties and elastic properties which is the aim of rock physics modelling. Therefore, any advances on rock physics studies can affect directly other disciplines involved within the reservoir life cycle.

Challenges in Rock Physics

Although rock physics application is very wide and impressive progress has been made in recent years but still there are a lot of challenges and unsolved problems. These challenges make it difficult in some scenarios to build a valid model or even build a consistent model with all disciplines. All of these indicate for the necessity of more research and study on this topic. Some of these challenges are:

- Subsurface is complex and velocities are controlled with a lot of factors which some of them will not be even known by combining all of the available information. Therefore, a rock physics model may fail in some places without any acceptable reason and may work at some other places.

- Different rock physics models have different assumptions which make them valid under specific conditions. This is resulted in a lot of rock physics models which the usage of them are constrained to satisfy some limiting conditions.

- Different measurements are made in different scales. Making a consistent model with all of the measurements which are referring to different scales is quite risky and difficult.

Conclusions

The increase in hydrocarbon demand and decrease of conventional hydrocarbon sources force the technology for developing advance tools to find new subsurface sources as well as optimize production from existing resources. Rock physics is one of these tools that can help with more accurate subsurface modelling, but there are lots of challenges and uncertainties which open possibilities for more research and study.

References

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