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Stochastic Modeling of Objects Extracted From High-Quality Seismic Data

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Abstract

In this paper we present an approach for modeling facies bodies based on detailed seismic interpretation of the reservoir's sedimentological architecture. The approach involves the use of a highly constrained stochastic object model to integrate directly the seismic facies interpretations in a 3D reservoir model. It fills the gap between the use of seismic data in a true deterministic sense, where the facies body top and base are resolved and mapped directly, and stochastic methods where the relationship between seismic attributes and facies is defined by conditional probabilities.

In the new approach the lateral geometry of the facies bodies is controlled by seismic interpretations on horizon slices or by direct body extraction. Facies body thickness and cross-sectional shape are defined by a mixture of seismic data, well data and user defined object shapes. The stochastic terms in the model are used to incorporate local geometric variability which is used to increase the geological realism of the facies bodies and allow for correct, flexible well conditioning.

The result is a set of 3D facies bodies which are constrained to the seismic interpretations and well data. Each body is defined as a "parametric object" which includes information such as: Location of the body axis, depositional direction, axis-to-margin normals, and external body geometry. The parametric information is useful for defining geologically realistic intrabody petrophysical trends and for controlling connectivity between stacked facies bodies.

Introduction

Conventional seismic interpretation involves interpretation of stratigraphic horizons and faults in vertical cross sections. With increasing quality and resolution, seismic data can also be used to interpret facies architecture in map view. The interpretation in map views is generally done using horizon slices which are aligned parallel to geological time lines.

Interpreted facies elements, including turbidite channels and a variety of bars and lobes, have been used very successfully for well targeting in many significant discoveries during the last decade or so. The interpreted facies have also been integrated in the static 3D model which is used for development planning and reservoir management. For thick, well resolved facies bodies, the integration of the seismic interpretation in the 3D reservoir grid is quite straightforward. For thinner facies bodies, the incorporation of horizon slice interpretations in a 3D model can be more challenging.

Where seismic quality is high it is often possible to interpret sedimentological features on horizon slices even where the facies bodies are thinner than the seismic resolution. Although the tops and bases of the bodies cannot be resolved independently from the seismic data, the total seismic response, including interference effects, often produces a pattern which is clearly responding to the facies architecture. The patterns seen on horizon slices can then be interpreted in terms of facies architecture. The approach described in this paper is aimed at providing a methodology which allows integration of these facies interpretations in 3D reservoir models.

The solution is based on using a stochastic object model to represent the facies as objects with a highly constrained geometry from the seismic interpretations. The parameters of the object model are primarily used to control thickness and shape in cross-sections. In general terms, the seismic interpretation defines the facies shape in map view and the parameters of the object model control the shape in cross-section. As will be shown later seismic and well data can also be used to constrain thicknesses. The stochastic terms in the model are used to incorporate local geometric variability from the idealised object