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## Effect of Formations Anisotropy on Directional Tendencies of Drilling Systems

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### Abstract

Interbedded formations hard/soft or soft/hard are a major cause of borehole tortuosity. Cases history have demonstrated that this tortuosity induces a higher torque and drag, running tubular problems, stabilizers wear, pipe damage and trajectory controlling problems. In some fields, shale formations have a tendency to cause wellbore deviations to undesired directions.

The formation anisotropy modifies the rock-bit and the bit-string interactions. Those interactions have to be fully understood in order to eliminate the phenomena of tortuosity.

To do so, an experimental drilling program has been carried out on a full-scale bench using various polycrystalline diamond compact (PDC) drilling bits (different gauges, profiles) in different formations (hard/soft, soft/hard with different interface angles).

Some directional tests have been also carried out in anisotropic shale at several dip angles.

Coupling a 3D bit-rock model with a 3D bottomhole assembly (BHA) model enables to predict the occurrence of tortuosity (due to the anisotropy) at small and large scales (micro and macro-tortuosity) and to evaluate feet by feet the response of all directional drilling systems (rotary, steerable motors or rotary steerable systems).

Deviations caused by formation anisotropy are separated into two phenomena. An initial deviation is caused by the rock-bit interaction. The experimental and theoretical results explain how the gauge length, bit profile, and dip angle, can affect the amplitude of this deviation. A second deviation is generated when the different stabilizers are sliding through the initial one. They can be amplified or attenuated according to the drilling system used.

The number of stabilizers and their positions, BHA characteristics and bit steerability have a considerable effect on these deviations.

A post analysis of some real drilling cases showed that, for a given drilling conditions including the formations anisotropies, it is possible to select the best drilling system minimizing the well tortuosity.

### Introduction

It is well recognized today, by the drilling industry, that deviations of well trajectories are influenced by the BHA design, borehole curvature and inclination, weight on bit (WOB), bit characteristics, and formation anisotropy<sup>1-2-3-4</sup>.

$$\text{Deviation} = F(\text{BHA, Bit, wellbore geometry, WOB, formation anisotropy})$$

This paper focuses on the effect of the formation anisotropy and especially on the following cases:

- Interbedded rocks: it consists in a suddenly change of the rock's mechanical characteristics.
- Laminated rocks: presenting an orthotropic mechanical behaviour. Mostly shales belong to this category.

The *effect of the formation anisotropy* on the directional behaviour of drilling systems has been observed on laboratory tests and on the fields, since a long time. When drilling laminated or interbedded rock, the first cause for deviation is attributed to the *cutter-rock interaction* and the *bit-rock interaction*.

Several studies were carried out to understand the interaction between the bit and isotropic rock but those concerning the anisotropic rock remain rather rare and incomplete. The goal of this paper is to describe a theoretical model validated and calibrated on full-scale bench in order to describe those interactions and show how they can affect the *directional behaviour of drilling systems*.

### Effect of formation anisotropy

The effect of geological formation anisotropy is often encountered in many drilling applications. Generally this effect is harmful and can generate many complications during drilling operations. Drillers have to learn, more and more, to drill with the natural formation deviation effect without using an expensive and not always justified means.

### Well deviation

Laurier<sup>5</sup> reports that, in south Bolivia, the trajectory control in the folded argillaceous series of Los Manos shale has been difficult. At the beginning, the trajectories were vertical and became very arduous to maintain, and inclinations up to 15° can be observed in less than 100 m. These directional