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Measuring Seismic Velocity Sensitivity To Production-Induced Strain at the Ekofisk Field

Aaron L. Janssen, Brackin A. Smith, and Grant W. Byerley, ConocoPhillips

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Abstract

In chalk reservoirs such as the Ekofisk Field, fluid flow and geomechanical effects combine to change both the location and properties of the reservoir and overburden. Pore pressure and fluid saturation changes cause reservoir compaction and perturb the elastic properties of the reservoir rocks. The overburden responds to the compaction with piston-like seafloor subsidence and length changes (strains). These overburden strains change the seismic velocity. The resulting velocity changes are observed on time-lapse seismic data as time-shifts that accumulate through the overburden.

These processes are being monitored by GPS surveys of the production facilities, repeat logging of radioactive marker bullets, repeat bathymetry surveys, core sample analysis, and time lapse seismic data. The goal of this paper is to combine these measurements to better understand the relationship between overburden strains, changes in overburden velocity, and resulting time-lapse time-shifts.

Introduction

Compaction and subsidence were first observed at the Ekofisk field, more than twenty years ago, as a loss of several meters of water clearance on the production platform. Since then, the compaction and seafloor subsidence has been studied in detail. Sylte and others (1999) characterized the compaction and subsidence effects by repeated logging and bathymetric measurements. Guilbot and Smith (2002) mapped time-lapse time-shifts at the top reservoir level and time-compaction of the reservoir interval between 1989 and 1999 (Figure 1). Combined with a second monitor survey in 2003, these results have been successfully applied in well planning and waterflood management. However, the overburden displacements and velocity changes were not well understood and could not be linked directly to movements in fluid

contacts or changes in reservoir pressure. Similar effects have been observed at the Valhall Field (Barkved and Kristiansen, 2005).

Hatchell and Bourne (2005a) propose a seismic and geomechanical model linking overburden time-shifts to reservoir compaction. This model assumes that the fractional change in velocity is proportional to the vertical strain. The main uncertain parameter in this model is the velocity sensitivity to rock strain (Referred to here as R).

Several studies have found R values between 4 and 6 fit time-lapse time-shift observations (Tura et al, 2005; Hatchell and Bourne; 2005). In most cases, the velocity sensitivity to rock strain cannot be measured directly at the field scale because of a lack of large scale strain measurements. In this study, we use compaction logs and repeat bathymetric data to determine these large scale strains and use time-lapse time-shifts to measure velocity changes. The initial results of this work are consistent with R values of at least 4 to 6 (Figure 4).