

The seismic quest for estimating heavy oil viscosity

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ABSTRACT

In heavy oil reservoirs, the enhanced oil recovery (EOR) is largely governed by the mobility of fluids. These EOR methods generally attempt to increase mobility by lowering the fluid viscosity. Hence, it is important to have knowledge of viscosity throughout the reservoir. While viscometers and geochemistry can be used to estimate viscosity from borehole samples, we attempt to estimate viscosity between boreholes. Recent research by Vasheghani and Lines (2009) shows the relationship between heavy oil viscosity and seismic Q . The estimation of Q (inverse attenuation) is attempted using a crossborehole tomography method of Quan and Harris (1997). The combination of Q tomograms and rock physics models is subsequently used to produce estimates of viscosity between boreholes. The details of this research are to be published in the upcoming PhD thesis of Vasheghani (under preparation).

INTRODUCTION

Much of the world's petroleum is to be found in heavy-oil reserves, with current estimates being over 4 trillion barrels. Canada and Venezuela are believed to have the largest heavy-oil reserves. EOR methods generally attempt to increase oil mobility by reducing its viscosity. Laminar fluid flow in porous media obeys Darcy's Law which for the single phase case is given by:

$$q = \frac{k}{\mu} A \nabla P \quad (1)$$

Here q is the volume flow rate, k is the permeability of the medium, μ is the fluid viscosity, and ∇P is the pressure gradient. Most EOR engineering recovery projects in heavy oil fields involve a reduction of viscosity. Therefore, it is essential to have some knowledge of viscosity to optimize production. Viscosity measurements have traditionally involved borehole measurements. In this project, we attempt to estimate viscosity between boreholes by accurate estimation of seismic Q and by use of rock physics to transform Q values to μ values. This viscosity estimation is computed for a heavy oil field in the Wabasca area of Northern Alberta.

VISCOSITY AND Q

The estimation of Q is best done by use of borehole seismic data (VSPs and cross-borehole data) where there are fewer uncertainties about the factors causing seismic attenuation. A reliable method for estimating Q is the seismic attenuation method developed by Quan and Harris (1997). The Quan-Harris attenuation tomography algorithm is coupled to the seismic traveltime tomography. Traveltime tomography is completed initially in order to compute the ray paths for Q tomography. Once Q tomography is completed, the Q tomogram is transformed to a "viscosity tomogram" by rock physics computations. The relationship between Q and μ is established using the Biot-squirt flow (BISQ) models described by Dvorkin et al. (1994). Figure 1 shows the $Q - \mu$ variation for the Wabasca field of interest. We note that for this "hockey stick curve" there is a nonuniqueness or ambiguity in the relation between Q and μ . In other words, for

a given Q value there are two possible viscosity values. This ambiguity was described earlier in a paper by Vasheghani and Lines (2009).

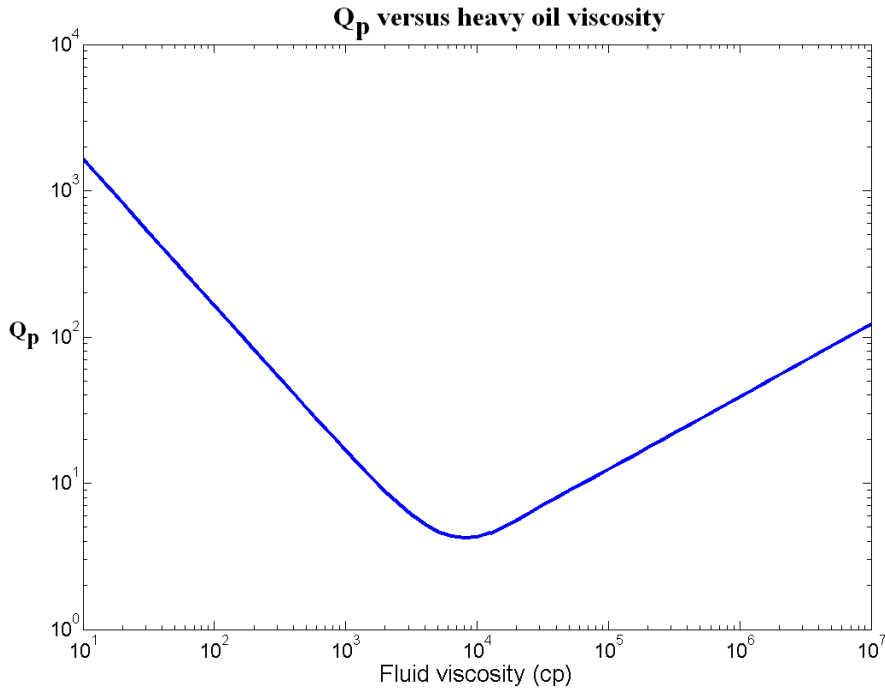


FIG. 1. The variation of Q as a function of fluid viscosity for Laricina’s Wabasca field.

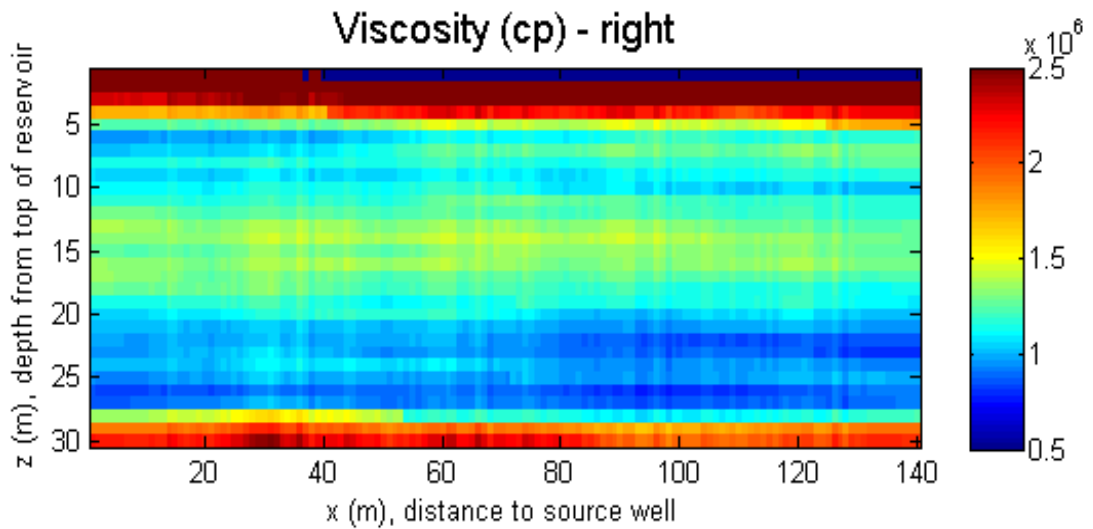


FIG. 2. The viscosity tomogram obtained by converting Q-tomogram values to viscosity tomogram values by using the right hand side of the “hockey stick curve” in Fig. 1.

In order to iron out this Q-viscosity ambiguity, we need to know whether our viscosity values are on the left or right side of this “hockey stick curve”. In other words, we need to know what range of viscosity values are most feasible in order to decide which part of the Q- μ curve is most appropriate. Normally, this is not a problem since we know the viscosity to within a couple of orders of magnitude.

VISCOSITY TOMOGRAM FOR A WABASCA HEAVY OIL SITE

For the Wabasca area, our target is the oil sands of the Grand Rapids Formation. Fluid viscosities are very high, in the 10,000-1,000,000 cp range as established by borehole measurements, so we choose the right side of the “hockey stick curve” in Figure 1. By using first arrival times for travelttime tomography and the frequency-shift centroid method for Q-tomography, Vasheghani computed Q tomograms using crosswell data for two wells separated by 140 m. By using the Q- μ relationships of Figure 1, the Q-tomogram is transformed into a μ tomogram as shown in Figure 2. Aside from the cap rock (red areas), it would appear that that the highest viscosities are in the middle of the Grand Rapids formation.

CONCLUSIONS

The most crucial parameter in the simulation of reservoir fluid flow is the fluid viscosity. From rock physics studies, it has been established that there exists a relationship between seismic Q and fluid viscosity. Vasheghani has used the combined travelttime and Q-tomography method described by Quan and Harris to estimate Q between boreholes. The Q tomogram is transformed to a viscosity tomogram using the BISQ rock physics relationships. While the Q-viscosity relationship is generally a nonunique relationship, it is believed that constraints exist that allow us to perform a mapping from Q to μ . This procedure is performed for data from Laricina Energy’s Wabasca field. Details of the computations and the interpretations are to be presented in Fereidoon Vasheghani’s PhD thesis, with an anticipated completion date of December 2010.

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