The Seismic Quest for Estimating Heavy Heavy Oil Viscosity

Fereidoon Vasheghani
CHORUS, Department of Geoscience , University of Calgary
vashegha@ucalgary.ca
and
Larry R. Lines
CHORUS, Department of Geoscience , University of Calgary
lrlines@ucalgary.ca

and
Joan Embleton
CHORUS, Department of Geoscience , University of Calgary
jembleto@ucalgary.ca

Summary

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 published in the 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. Fluid flow in its simplest form is given by Darcy's Law which for the single phase case is given by:

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

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 in heavy oil fields involve 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.

Methodology

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).

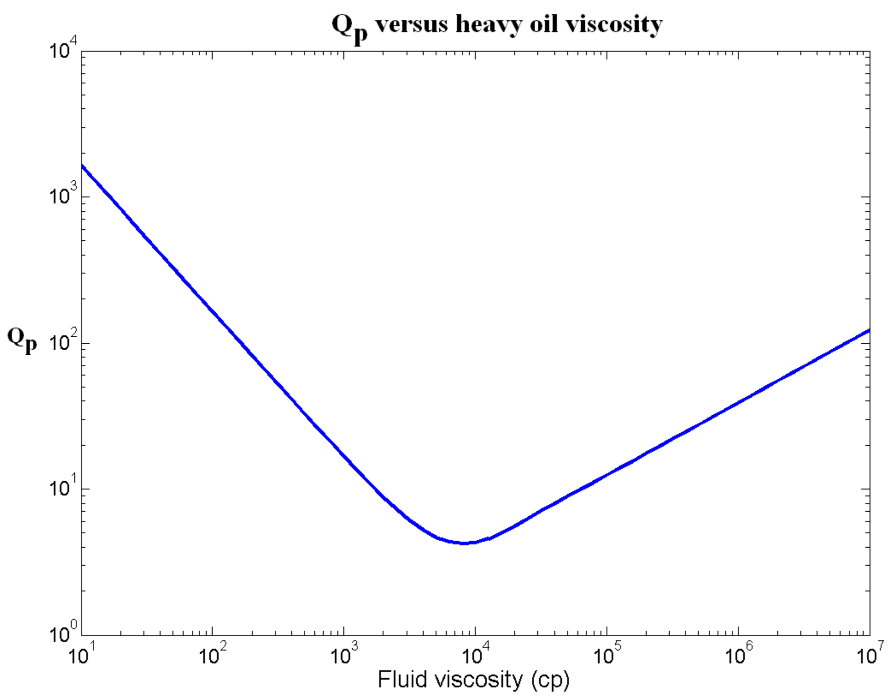

Fig. 1. The variation of Q as a function of fluid viscosity for Laricina's Wabasca field.

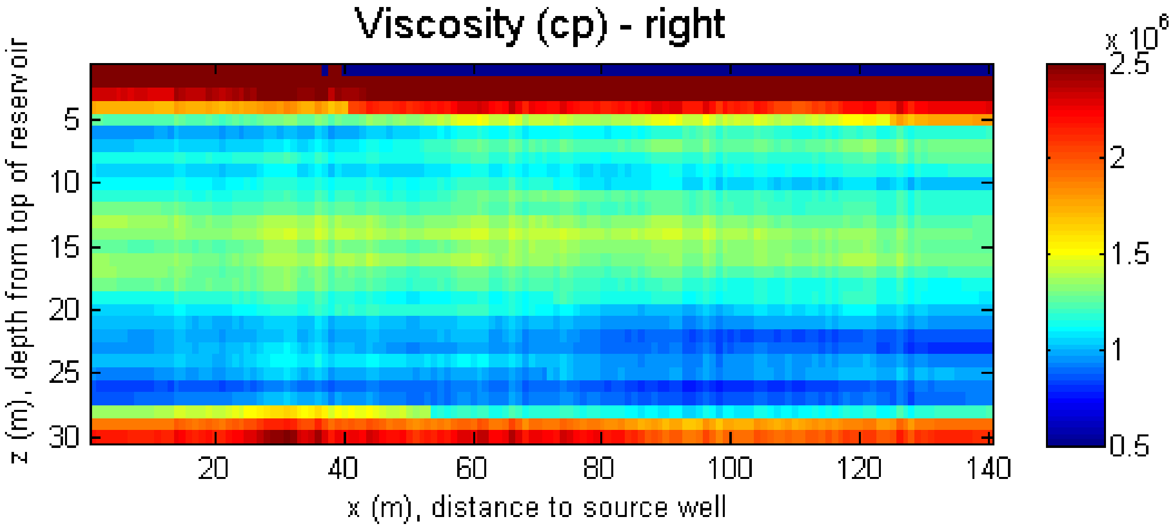

Fig. 2. The viscosity tomogram obtained by converting Q-tomogram values to viscosity tomogram values by using the right hand side of the “hockey stick curve” in Fig. 1.

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 and can decide which part of the Q- μ curve is most appropriate.. Normally, this is not a problem since we know this viscosity within a couple 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 traveltime tomography and the frequency-shift centroid method for Q-tomography, Vasheghani computed Q tomograms using crosswell data for two wells separated by 140m. 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 traveltime 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 relationahip is generally a nonunique relationship, it is believed that constraints exist that allows 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 anticipated completion date of February 2011.

Acknowledgements

The authors thank AICISE, CHORUS, CREWES and NSERC for financial support of the researchers. We thank Laricina Energy for supplying the crossborehole data and we thank Schlumberger for supplying software and processing assistance in crossborehole tomography.

References

Dvorkin, J., Nolen-Hoeksema, R. and Nur, A., 1994, The squirt-flow mechanism: macroscopic description, Geophysics, 62, 895-905.
Quan, Y., and Harris, J., 1997, Seismic attenuation tomography using the frequency shift method, Geophysics, 62, 895-905.
Vasheghani, F., and Lines, L., 2009, Viscosity and Q in heavy-oil reservoir characterization: The Leading Edge, 856-860.