

# Interpreting Pumping Test Data from Fractured Aquifers – The Dual Porosity Model.

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## Summary

Aquifer testing in fractured aquifers (e.g. carbonates) in the oil sands is gaining momentum because of the need of finding alternate water sources of non-saline water for use in steam assisted gravity drainage (SAGD) and cyclic steam stimulation (CSS).

Flow in fractured aquifers is better known as linear (single fracture) or bilinear type (dual porosity) and like conventional aquifers, interpretation relies on analytical solutions that best fit to the aquifer settings and hydraulic regime. Application of analytical solutions is a straight forward process; however, it requires of choosing the data segment that best corresponds with the flow regimen acting in the vicinity of the wellbore.

This work illustrates the process of using curve-types and flow regimen diagnostic plots to select appropriate data segments for interpretation of a single well pumping test conducted in the Grosmont Formation. The approach allows interpreters to focus on relevant data, avoiding multiple interpretations that may result in ambiguous conclusions.

## Introduction

Dual porosity flow behaviour occurs when two different media are involved in the flow process: a higher-permeability medium that produces fluid into the well and a lower permeability medium that recharges the higher-permeability medium (Gringarten, 1987). Most of the current guidelines to recognize dual porosity systems from well tests were summarized in type-curves by Gringarten in 1987. In essence, Gringarten idealized type curves for the different flow phases, starting in a single porous medium, through a transition zone and finally through the second porous medium.

Using type-curves to select the data segment that best represents aquifer behaviour is based on shape correlations, which has some uncertainty due to similarity with curve shapes from other aquifer behaviours (e.g. leaky aquifers). Therefore, confirming flow behaviour before applying analytical solutions is essential. Selection of data segments can be improved by initial screening of the flow regimen in the vicinity of the wellbore using diagnostics plots.

## Methods

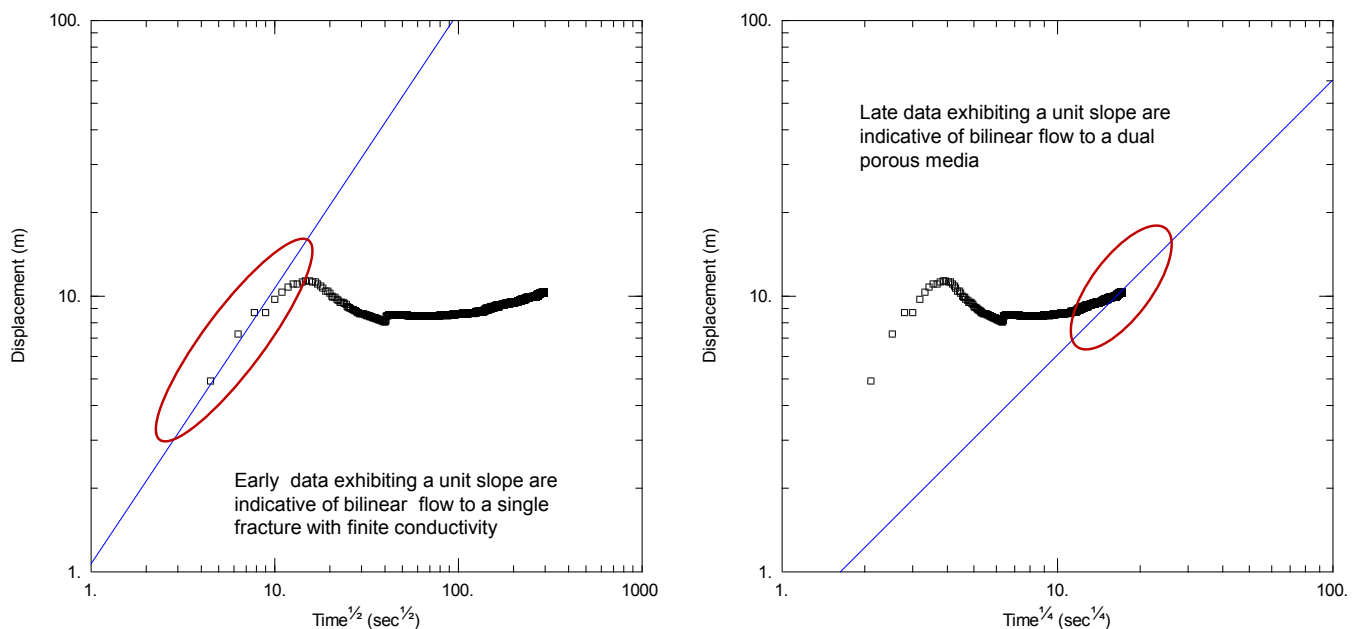
Curve-types describe the behaviour of the interpretation model corresponding to the well and the reservoir, and included various flow regimes that successively dominate during the test. Examples of log-log type-curves plots for various interpretation models are presented in Gringarten (1987). Similar type-curves have been simulated by Jabbarai, et al., 2012.

Modern well test interpretation identifies several different types of flow regimes, the most common being radial, linear (fracture or channel) and bilinear (dual porosity). Identification of flow regimen is achieved by the use of diagnostic and derivative plots as presented by Horne, 1995, and Aqtesolv (in Midwest Geosciences, 2013). On a log-log bilinear flow plot, early time data exhibiting unit slope is indicative of bilinear flow to a single fracture with finite conductivity. On a log-log bilinear flow plot, exhibiting a unit slope is indicative of bilinear flow to a dual porosity media.

## Examples

A single well pumping test was conducted in a 30m section of the Grosmont Formation to evaluate its aquifer potential. Water was pumped at a constant rate of 345 m<sup>3</sup>/day for a period of 24 hours followed by a 24-h recovery period.

Aquifer behaviour resulting from pumping (drawdown vs. time), along with the interpretation of the flow type is presented in Figure 1. Identification of data segments corresponding to linear, transition and bilinear flow behaviour is presented in Figure 2. Thus, late time data (greater than 60 minutes) was selected as corresponding with dual porosity and later used to carry out interpretations.



**Figure 1: Determination of flow regime. a) Bilinear flow. b) Dual porosity flow**

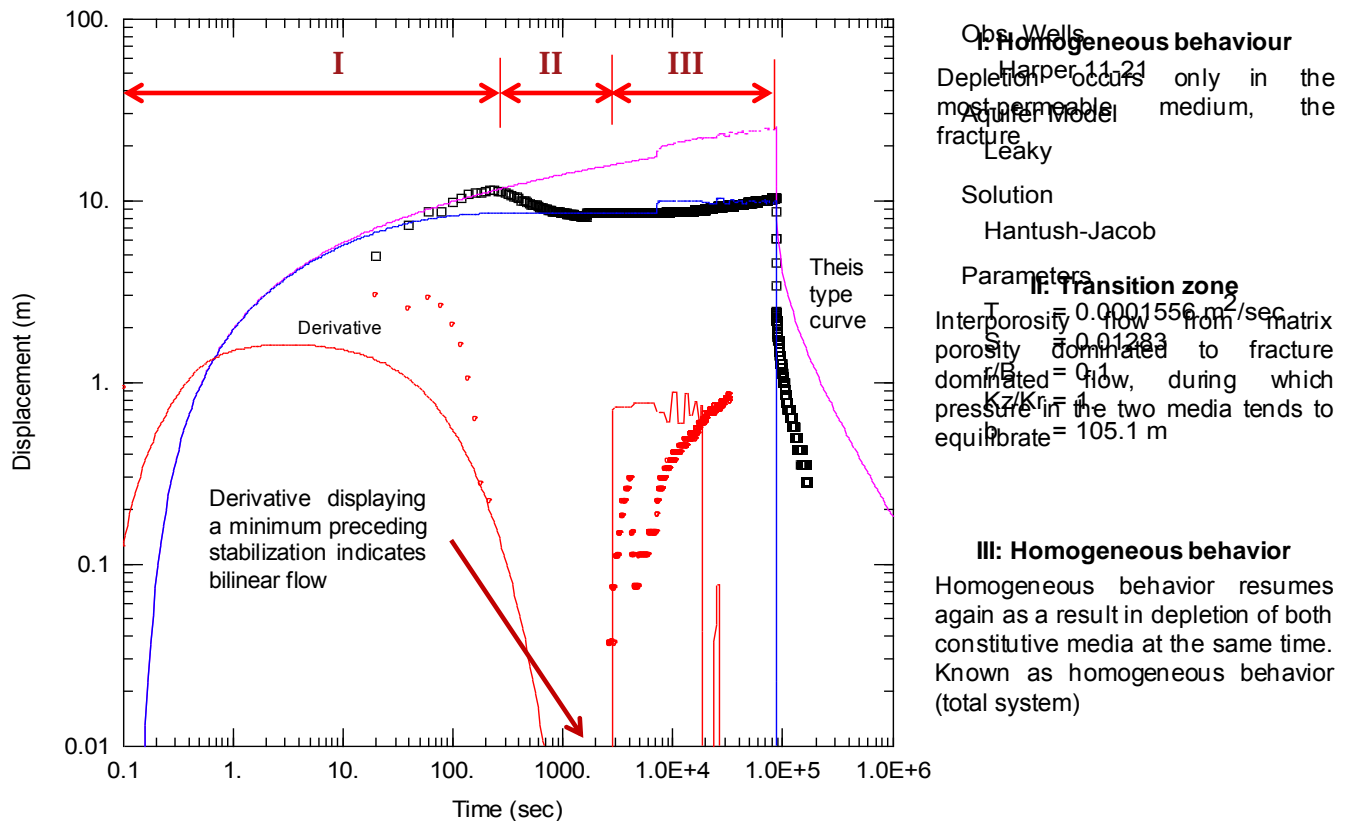
The analytical solutions, Theis (1935), Theis-recovery (1935) and Gringarten-Whitherspoon (1974) were applied to derive aquifer Transmissivity and hydraulic conductivity (Table 1). Consistent  $T$  values, in this case, suggest that flow in the aquifer is mainly driven by fracture media with little influence of the porous matrix. This is supported by the fact that the matrix is bitumen saturated with low water content. Water production was interpreted as due to preferential flow.

**TABLE 1. Aquifer properties derived from fractured aquifer testing**

Analytical Solution	T (m <sup>2</sup> /s)	K (m/s)
Theis (1935)	0.000477	1.6E-05
Theis-Recovery (1935)	0.000453	1.5E-05
Gringarten et al., 1974		1.3E-05
<b>Geometric Mean</b>	<b>4.65E-04</b>	<b>1.46E-05</b>

**Conclusions**

The use of type-curves combined with flow regimen plots is useful to select the data segment that best represent dual porosity aquifer behaviour. In this particular case, it led to a consistent evaluation of the aquifer properties, Transmissivity ( $T$ ) and hydraulic conductivity ( $K$ ), while identifying that water production is due mainly to preferential flow. The approach allows interpreters to focus on relevant data, avoiding multiple interpretations that may results in ambiguous conclusions.



**Figure 2: Flow behaviour zones in fractured aquifer testing**

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