Flow description of gas well in basement granite reservoir from well test analysis

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Abstract. A sweet gas exploration well, penetrating 3286 feet thickness of Granite Basement with 200 feet thickness of extensive fracture was tested. Initial step was to study all geological and petrophysical aspects of reservoir and well. These data were used to obtain the sense of reservoir shape model and its fracture flow behaviour. Interpreting the log gives the presents of partial fracture and open fracture, which are shown in the early time region as a fracture dominated flow and very small wellbore storage effect. The bilinear flow before middle time region and followed by two porosity fracture model at middle time region are shown afterward. Constant pressure circle boundary is shown in the late time period. In summarized, the well flow model is in infinite acting conductivity with two porosity pseudo steady state reservoir model and constant pressure circle boundary. The permeability is 1.45 mD, with -0.52 skin and 1962 Psia reservoir pressure; meanwhile the fracture coefficient is 50 mD-ft, storativity is 0.51, and interporosity flow coefficient is 4.38x10^-6 mD-ft. All well and reservoir data pertaining well test is very important for getting a reliable well test interpretation result; to get better understanding reservoir flow behaviour; in this case the reservoir is tight with expected better reservoir outside circle boundary.

1. Introduction

Well Tests are performed in the early development of oil or gas field. Along with drilling, logging, and other geological tasks; well test analyses would benefit much on reservoir fluid flow description, which leads to further manage the field development, in order to get an optimum hydrocarbon recovery [1]. A well test in this case is the Pressure Transient Test; or a test conducted in a well for at certain period of time, while monitoring its production and its bottom hole pressure.

Since the subject well is a gas well; a gas well test usually is started by flowing a series of production rate for several time, and then the well is shut in for Pressure Build Up (PBU) test. This PBU test is then analyzed vigorously in order to get the flow behavior of the reservoir, and at the same time also the reservoir description.

The drilling, logging, and other geological data shows that the subject formation is a basement formation, which is formed from solidified volcanic rock. Even though the presence of hydrocarbon in the basement reservoir is not a common reservoir, but it is found all over the world. Most of hydrocarbon reservoir are from stand stone and carbonate rock reservoir, which have porosity. This porosity bears the reservoir fluid to be exploited, which is called matrix porosity. In the basement reservoir, there is no porosity; however, a micro fracture behaves as a matrix porosity; which contains hydrocarbon. In addition to this micro fracture, there is also large fracture exist in the subject reservoir [2].

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The well test analyses will not only confirm the presence of these two types of fractures, but also will give additional reservoir flow information such as initial reservoir pressure, transmissivity, permeability, formation damage, storativity, interporosity flow coefficient, and distance to a boundary. It is necessary to have reliable well test interpretation result; to get better understanding reservoir flow behaviour; in this case the reservoir is tight with expected better reservoir outside circle boundary.

2. Methodology
Pressure Transient Test basically is a reservoir test by giving pressure disturbance to the reservoir by allowing the well to flow, and/or shut in. This disturbance will spread throughout the reservoir. By measuring the pressure in the well bore during testing, and analyzing it; the reservoir flow behavior would be understood.

The most common pressure transient test is pressure build up (PBU) test. As compared to pressure draw down (PDD) test, PBU test gives a constant production rate of 0 (zero). A constant production rate is the first assumption of the basic equation of pseudo steady state radial flow in reservoir. The most common PBU test was introduced by Horner [3]. By adopting principle of superposition, Horner plot Horner time ratio (HTR) in the x-axis and pressure in the y-axis. HTR is an addition of production time and build-up time, divided by build-up time. Presently, Horner plot is used as a reference or comparison to log-log diagnostic plot pressure derivative dimensionless type curve analyses.

Log-log diagnostic plot pressure derivative dimensionless type curve analyses was first introduced by Gringarten et al. for the dimensionless pressure drop [4]. However, since the matching curve of data and type cure will have a lot of uncertainty in the pressure drop type curve; Bourdet et al. came up with dimensionless pressure derivative plot, along with Gringarten plot [5]. The type curve of Gringarten and Bourdet, answers the flow behavior of reservoir and the reservoir description itself.

Figure 1 is the type curve for infinite acting radial flow model, which is the basic model of reservoir fluid flow to the well. The group of curves in the upper part are pressure different Gringarten curves for various C_D e^{2s} values, meanwhile the group of curves in the bottom are pressure derivative Bourdet curves, and also for various C_D e^{2s} values.

![Figure 1. Infinite acting radial flow model.](image)

Figure 2 is the flow regime identification tool, to identify whether the flow is affected by the wellbore effect or directly see the linear or bilinear fracture flow in reservoir, or spherical flow in reservoir in the
early time. This identification tool to be used for Bourdet pressure derivative. In the middle time, this identification tool, to be used to see radial flow. However, this identification tool is not included the late time period, since late time period shows reservoir boundary seen by the well test. If the curve is upward direction in the late time period, there is no-flow boundary.

![Flow regime identification tool](image)

**Figure 2.** Flow regime identification tool.

Initially, rock and fluid property data are obtained from various sources; drilling, logging, and geological and geophysical data. In the case there is no available data, correlation is used. Production rate and bottom hole pressure data are obtained during the well test operation.

The above data are needed to be verified, especially production time, the rate of each production time, and when is the build-up time. Since the production rate is not constant, it needs to pick-up the representative rate with stable pressure response as reference. Other data usually is already being verified its accuracy, but still needs to see it logically.

Well test analyses software was utilized in matching the pressure response data and type curve. Initially, the interpretation is run by using the most simple model; wellbore storage model and radial flow infinite acting model. Afterward the closest flow model to the reference drilling, logging, geology, and geophysical data is picked up to get reservoir parameters and model.

### 3. Results and discussion

Plot of shut-in pressure and flowing pressure difference during PBU versus shut-in time; and pressure derivative versus shut-in time, are obtained in one graph.

![Type curve pressure derivative](image)

**Figure 3.** Type curve pressure derivative.
Figure 3, is the match curves, between type curve in solid line curves and test data in marker line. The green marker is pressure drop data, and the red marker is the pressure derivative data. These two data align with the type curve of black solid line. The pressure drop data and pressure derivative data in the early pressure build up match with type curve of finite conductivity. After that it is followed by the two-porosity pseudo steady state flow around x-axis of dt between 0.3 and 3. When dt between 3 and 10, the infinite acting radial flow is reached. In the end or late time region, boundary of circle-constant pressure boundary is found. The reservoir model is summarized in table 1.

**Table 1. Model interpretation.**

| Model       | Type                        |
|-------------|-----------------------------|
| Well        | Finite Conductivity         |
| Reservoir   | Two Porosity PSS            |
| Boundary    | Circle - Constant Pressure  |

During infinite acting radial flow or middle time region of figure 3; reservoir parameters are obtained, and they are summarized in table 2. The flow characteristics of the well is quite unsatisfactory, even though there is fractures existence in the reservoir. However, the circle constant pressure boundary gives opportunity for the reservoir beyond the boundary has a much better reservoir flow characteristics.

**Table 2. Reservoir parameter.**

| Parameter                          | Value | Unit   |
|-----------------------------------|-------|--------|
| Permeability (k)                  | 0.11  | mD     |
| Skin (s)                          | -0.52 | -      |
| Storativity (Ω)                   | 0.51  | -      |
| Interporosity Flow Coefficient    | 4.4x10⁶ | mD.ft  |
| Distance to Boundary              | 50.5  | ft     |

The result discussion is started with division of three flow regions; early time region, middle time region, and late time region. Figure 4 shows the explanation each time region.

**Figure 4. Analysis results.**

In the early time region, limited well bore storage effect was found, which then directly followed by linear flow of fracture, and then continued by bi-linear flow of fracture; both in the formation. Meanwhile, due to fracture extension, the linear flow could be seen a little in the middle time region, also. Middle time region shows interporosity transient flow or dual porosity reservoir, which then
followed by pseudo radial flow to obtain permeability and skin. In the end of late time region, the pressure derivative shows a boundary, this boundary is circle boundary, with a distance of quite small. Since the formation is fracture basement formation from geological data, it is confirmed by the existing of fractures in the well test. In addition to it, dual porosity also confirms the existence of open fracture and partial fracture; partial fracture behaves as matrix porosity, while open fracture behaves as a fracture in sandstone or carbonate rocks. These two fractures are shown in the Magnetic Resonance Imaging Log and Extended Range Micro Imager. The circular boundary, could be thought that the extend of both open and partial fractures are limited inside the circular, but there is better quality reservoir beyond distance from circular boundary.

4. Conclusion
Conclusions could be taken from these well test are:

- Well the model is finite conductivity fracture reservoir, which is confirm by geological data that the reservoir is basement fracture reservoir.
- The open fracture and partial fracture in the basement reservoir are also seen in the well test as dual porosity pseudo steady state model reservoir.
- There is an existence of circular constant pressure boundary, means that further away from the well, there is better quality of reservoir to be exploited.
- The reservoir basement has very low permeability, with good skin factor, but the hydrocarbon storativity in the open and partial fractures are almost the same, with mediocre quality of flow between partial and open fractures.

The reservoir description is defined very well in this well test, to further exploit the reservoir from this basement reservoir, since the reservoir flow character will be better outside circle constant pressure boundary.

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