Identifying the Potential in Complex Basement Reservoir: Advance Application of Borehole Images and other Openhole Logs, A Case Study from Western Offshore, India*

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Abstract

Exploring unconventional reservoirs for hydrocarbons has been of key interest for major oil companies across the globe for some time now, and basement remains one the most prolific candidates. Mapping basement reservoir properties is always a big challenge due to drastic vertical and lateral variations in porosity and permeability. However, recent advances in measurement and evaluation techniques have provided an advantage for low-porosity, low-permeability basement exploration. This study focuses on one such methodology for characterization of these reservoirs using static and dynamic well data. Two wells were selected from the Heera Field of western offshore India (Figure 1). The stratigraphy of the area is shown in Figure 2.

Formation resistivity micro-imager data, along with acoustic and nuclear magnetic resonance datasets were used to characterize rock texture and fracture network. Validation of the open fracture zones on image has been done in light of conductivity data from images and Stoneley fracture analysis from acoustic logs. Borehole images were further utilized to derive fracture density and also to estimate aperture and porosity, which were calibrated with the borehole-sonic-derived results to estimate the gross voidage in the basement rock. However, in fractured basement rock, the average porosity is usually very low; hence, fracture transmittivity or permeability plays a critical role in estimating the fluid movement in a basement rock. Two methodologies were used to derive the permeability in the basement rock. The first methodology was based on the advanced rock heterogeneity analysis, which was performed to get the raw permeability indicator (RPI) based on conductivity values on the image log. The RPI was further scaled using a data function to read

permeability. Similarly, a second permeability determination method was used utilizing fracture aperture and fracture density of open fractures in the heterogeneous basement. The estimated permeability results from these two approaches were further validated with dynamic formation tester data. The general workflow followed for the present study is shown in Figure 3.

The derived permeability, along with the dynamic dataset, further validated the presence of possible sweet zones within the reservoir (Figure 4 and Figure 5). In one of the wells, the permeability results added vital clues for explaining the non-productivity of the basement section. This methodology proved to be of immense help in characterizing the heterogeneous basement reservoir, and thus it can be further used to optimize the production.

Conclusions

Calibration of permeability results for Well X and Well Y are shown in Table 1 and Table 2 respectively. From the results we obtained, it is quite evident that image-derived permeability is in good accordance with nuclear magnetic resonance and dynamic datasets. Hence, permeability can be quantitatively estimated for fractured basement reservoir using image logs with the able integration of advanced open hole logs, mud loss data, dynamic well testing and production logging data. First of all, FMI along with acoustic log data provide an excellent idea of the open fracture distribution in the basement, while heterogeneity analysis produces a very good raw permeability indicator (RPI) in fresh basement. Heterogeneity analysis along with fractures provide a good idea of the basement character, and subsequently connectedness and fracture-derived permeability provides a very good idea about reservoir properties. Hence, image-derived permeability, along with other data sets can be extremely helpful in the selection of good zones for testing and also provide a fair estimation of wellbore permeability; the results should be incorporated to more fully integrate borehole information into reservoir simulation studies.

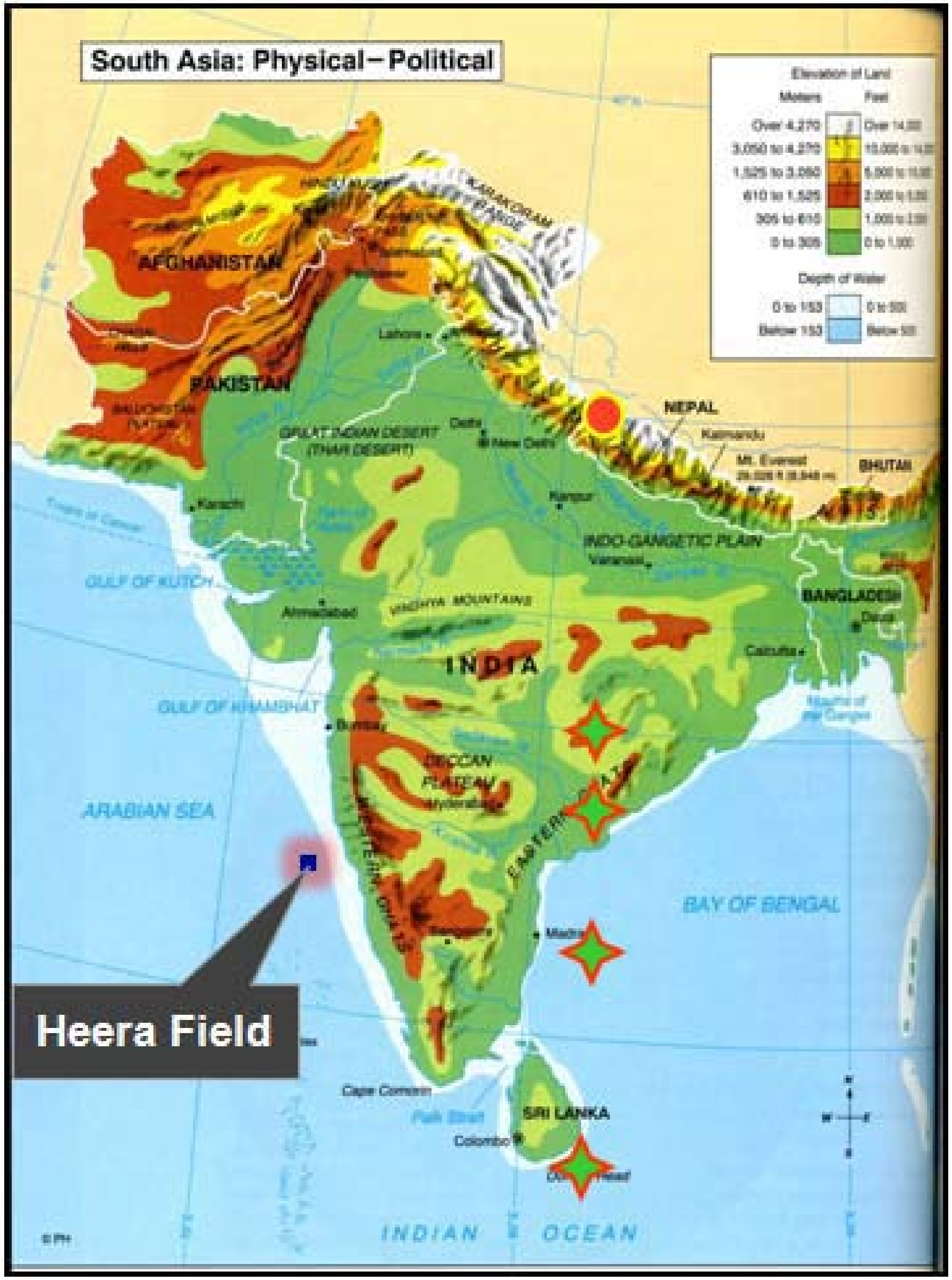

Figure 1. Location of the study area.

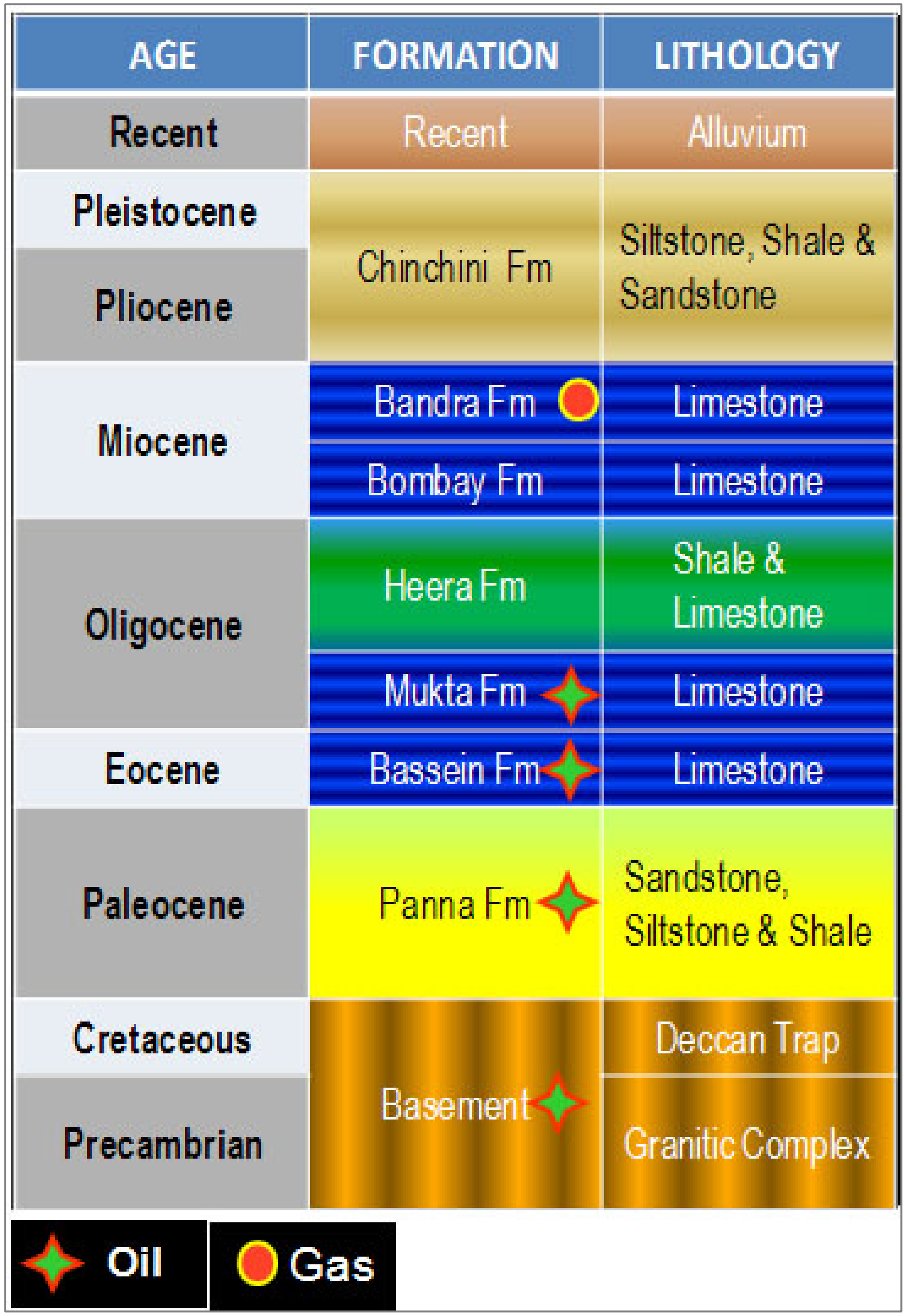

Figure 2. Stratigraphy of the study area.

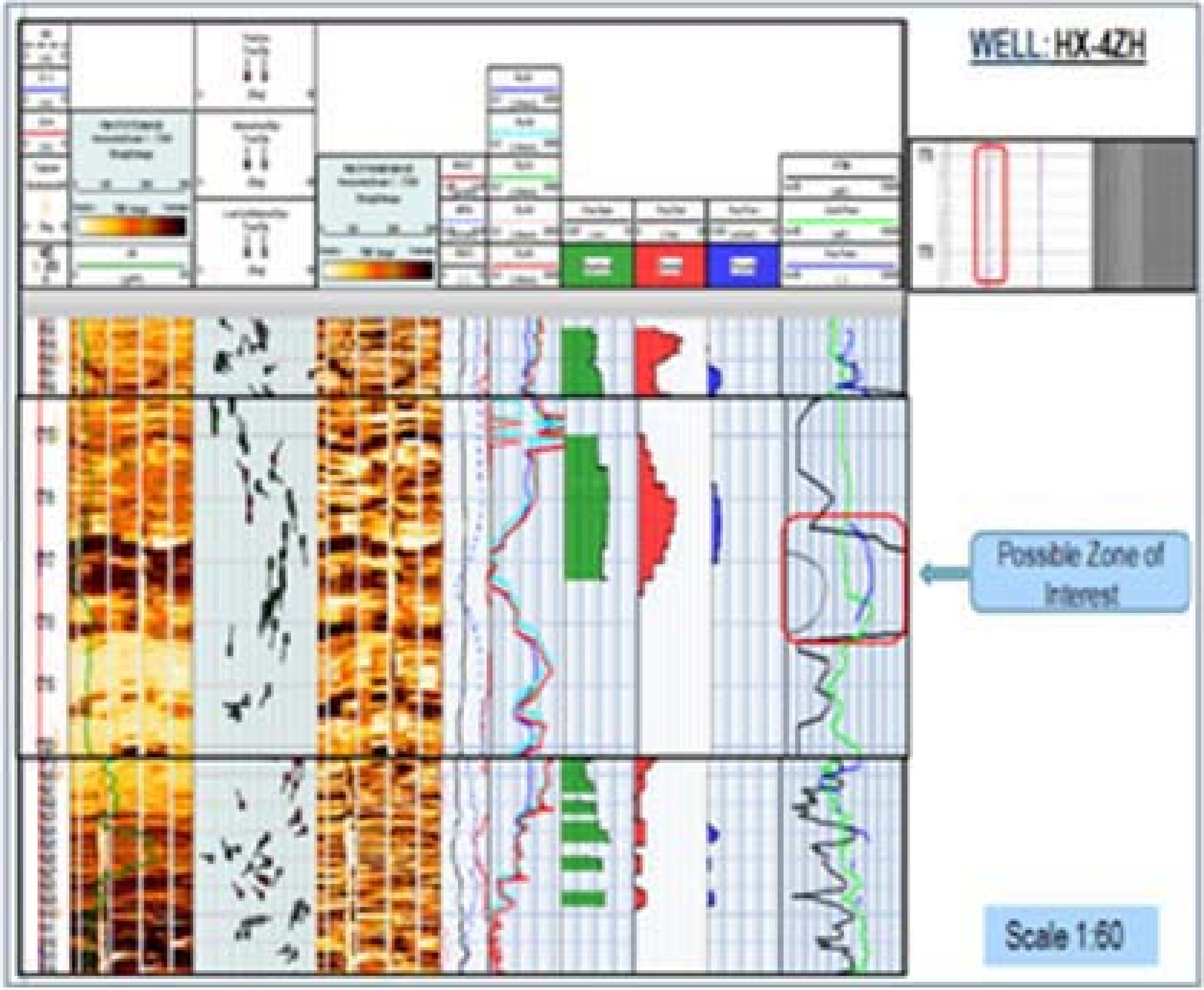

Figure 3. Schematic illustration of workflow.

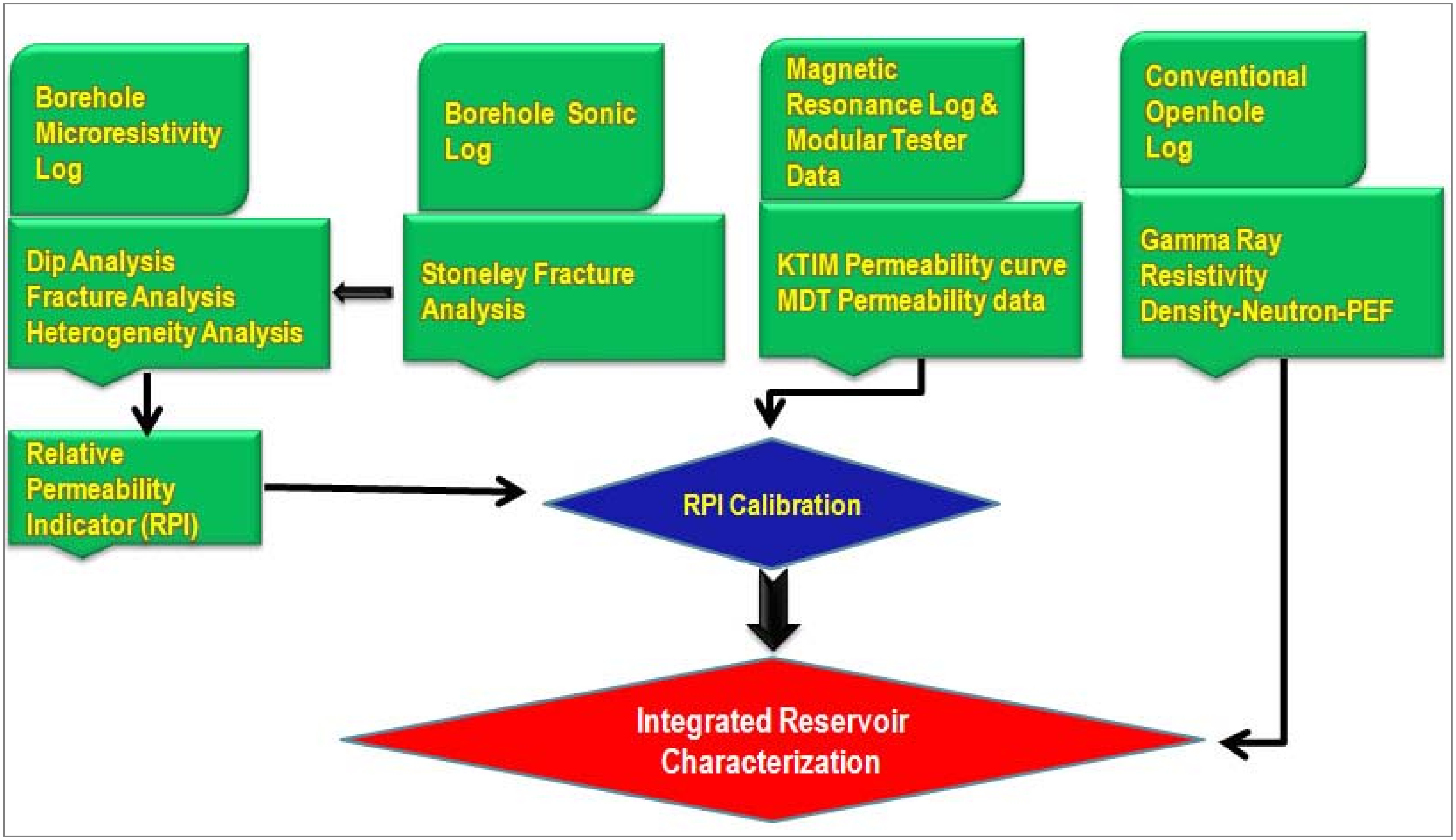

Figure 4. Case Study 1, Well X.

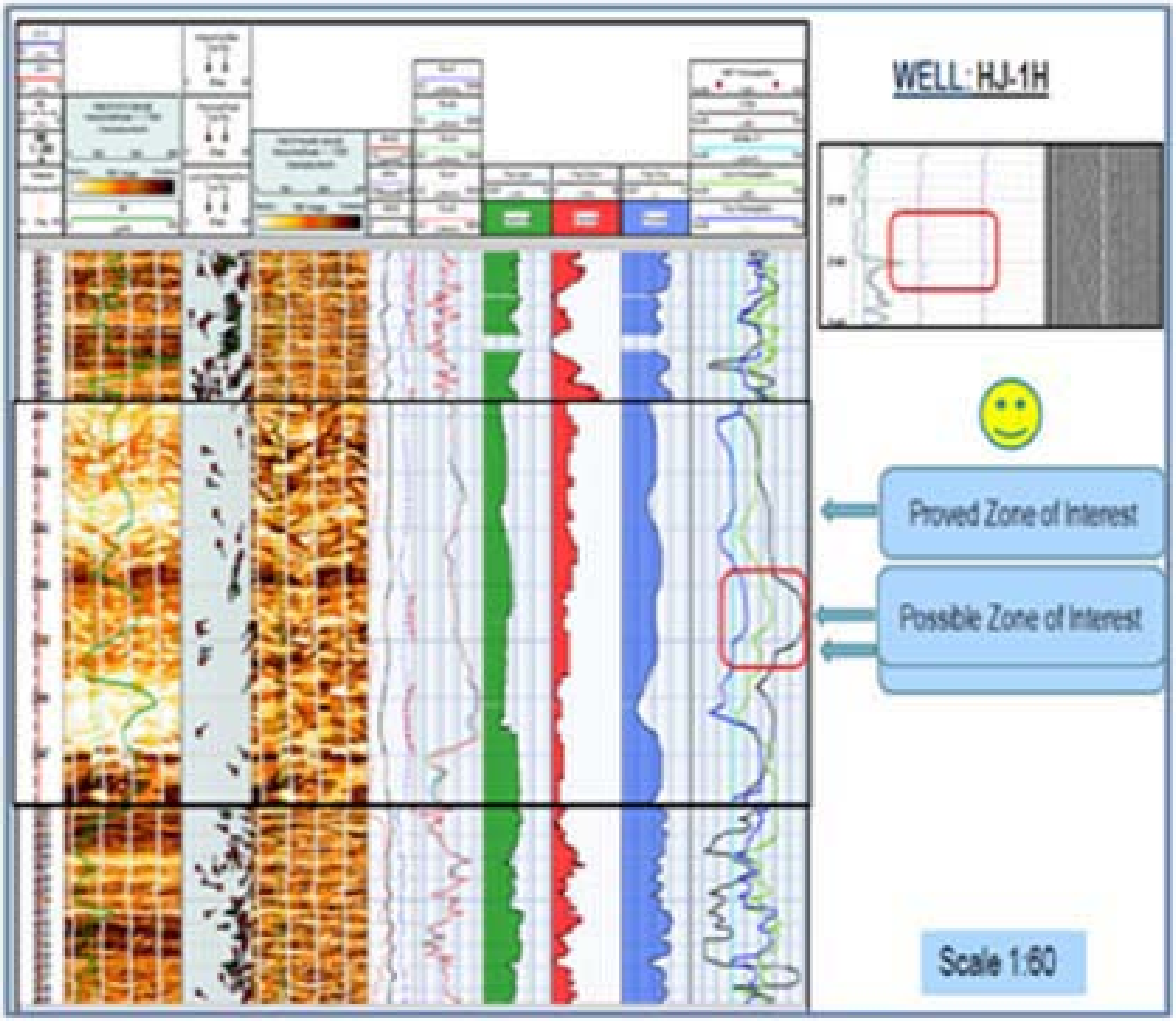

Figure 5. Case Study 1, Well Y.

Summary of Results for the Dual Packer Stations

Test Depth (MD) (m)	Openhole Formation Thickness considered (h) (m)	Fluid Type	Perme-ability (mD)
XX03.06	1	Oil	19.7
YY11.59	1	----	----
ZZ36.69	1	----	----

Calibration of Permeability Results

Depth Zone (MD) (m)	Fluid Type	MDT Derived Perme-ability (mD)	KTIM Derived Perme-ability (mD)	Con. Connectedness Derived Perme-ability (mD)	Fracture Derived Perme-ability (mD)
XX8.4-XX04.4	Oil	19.7	High	High	High
YY05.2-YY12.3	----	----	High	High	Moderately High
ZZ36.2-ZZ46	----	----	High	High	Moderately High

Table 1. Calibration of permeability results for Well X.

Calibration of Permeability Results

Depth Zone (MD) (m)	Fluid Type	MDT Derived Perme-ability (mD)	KTIM Derived Perme-ability (mD)	Con. Connectedness Derived Perme-ability (mD)	Fracture Derived Perme-ability (mD)
XX06-XX17.2	----	----	High	High	High

Table 2. Calibration of permeability results for Well Y.