



Formation Evaluation of Basement reservoirs of Borholla-Changpang field, Upper Assam Shelf, India.

*Manisha Chaudhary, *Ajay Kumar, Paramanand, Beena Jhaldiyal ; ONGC Ltd.*

*Kumar_ajay14@ongc.co.in

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Abstract

The first hydrocarbon discovery from the basement rocks in India was encountered in the year 1970 in the Borholla-Changpang field of Upper Assam Shelf. The fractured/weathered Basement and the Basal Sandstone Formation constitute the primary reservoir in this field. Although the presence of hydrocarbon is established in the basement, a detailed analysis of their reservoir nature using well logs and cores has not been carried out so far. In this study, petrophysical core studies were carried out and integrated with well-logs to evaluate the reservoir nature of the basement of the Borholla-Changpang field. The study shows that although the basement is mostly massive and devoid of any reservoir properties, there are zones of weathering and fractures that have provided the essential porosity and permeability in an unconventional basement. The study identifies four facies based on their capability to hold and flow hydrocarbon within the drilled basement and helps in reducing the uncertainties in the formation evaluation of the basement in the study area.

Introduction

The Borholla-Changpang field is located in the Dhansiri Valley area of Upper Assam plains in the vicinity of the Naga foothills and about 30 km away in South of Jorhat City (Gupta et al., 2021) (Fig. 1). The field covers approx. area of 30 sq. km. (Goswami et al., 2001; Ahmed et al., 1993). Upper Assam Shelf (UAS) encompassing the geographical extent of Dhansiri Valley forms a thrust-bounded basin, which had undergone multiple episodes of tectonism (Ranga Rao, 1993). Geologically, it is a singular structure. In Upper Assam shelf (UAS), hydrocarbon pools are established and exploited from stratigraphic sequences ranging in age from Pre-Cambrian fractured basement to Mio-Pliocene sequences. Granitic - gneissic complex constitutes the

basement for sedimentary sequences of Tertiary age (Goswami et al., 2001; Prabhu and Murali, 1987; Singh et al., 2012). As most of the production from the field is from the Basement, it becomes important to evaluate and understand the reservoir nature of the basement through integrated logs and core studies. In this study, the petrophysical properties such as porosity, permeability and density were determined on core samples, and a new methodology is adopted to identify the zones having reservoir properties within the drilled basement.

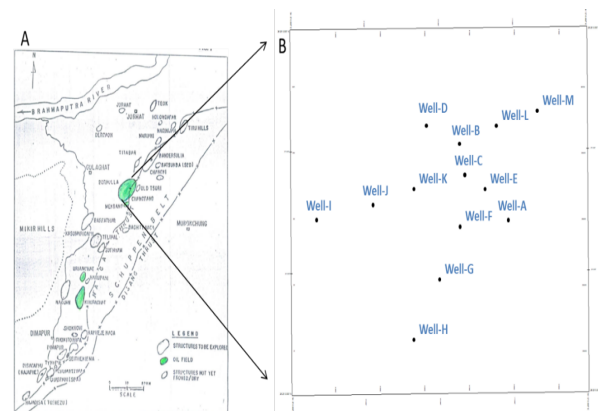


Fig 1. A) Location map of Borholla-Changpang field. B) Key wells used in the study.

Methodology

Petrophysical core studies were carried out on 21 core samples from 6 wells. The well log data of 34 wells were evaluated and integrated with core studies for detailed analysis of basement reservoirs. Porosity, permeability, grain and bulk density were measured for 21 core plugs using KEYPHI equipment. Porosity was measured using Boyle's law and permeability using Darcy's law. Integrated core and well log studies helped in the determination of rock typing, reservoir facies and their distribution across the field.



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Results and Discussions

1. Core studies

Porosity, permeability, grain and bulk density were measured on 21 core samples from 6 wells drilled in the basement. Measured Porosity values against all 21 core samples are shown in Fig.2A. It is observed that the porosity ranges between 0.9 to 4.76 % and high porosity values are observed in samples from the weathered part of the basement. The permeability values are shown in Fig. 2B. The value ranges between 0.03 to 0.2mD.

Measured Grain and bulk density are plotted in Fig. 2C. The difference between these two values, which is indicated by the blue color in the figure, shows the presence of porosity. The value of grain density is higher for basement rocks and the lowering of the bulk density shows the presence of fluid in the medium and hence the difference between these two values indicates the presence of available pore space. The plot gives a qualitative estimate of the presence of porosity in the core samples.

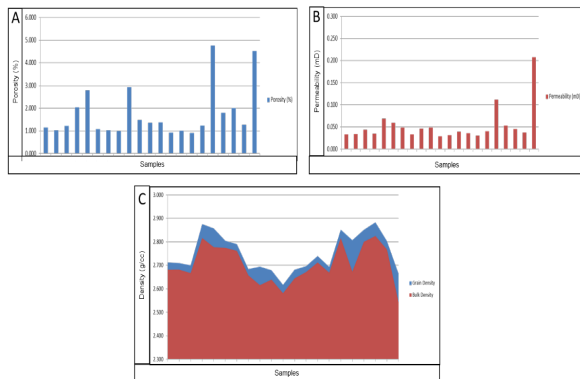


Fig 2. A) Measured Porosity and B) permeability values in the studied basement core samples. C) Bulk and grain density for basement core samples.

Core studies show that the weathered basement samples have good porosity and permeability. The next step is to identify the zones within the basement that have these reservoir properties and can act as storage for fluids within the drilled basement.

2. Identification of rock types:

The previous studies in the Borholla-Changpang field indicate that the Basement majorly consists of granite and granite gneiss (Goswami, 2001). Granite is observed in the shallow intervals and Granite gneiss in deeper intervals in the studied wells. RHOB-NPHI cross plots have proven to be helpful in the identification of these two rock types. Density values of less than 2.72 gm/cc are observed in granite, while high-density value ranging from 2.72 to 3 gm/cc are observed in the granite gneiss intervals. Granite and Granite Gneiss are observed from the cross plots for well BH-A in Fig 3. Log characteristics for granite and granite gneiss are given in Table-1 (Chaudhary et al., 2021).

| Rock types/ Log Values | Granite (Acidic Igneous Rock) | Granite Gneiss (Metamorphic Rock) |
|---------------------------|--|---|
| GR | Very high (150-350 GAPI) | Low (0-150 GAPI) |
| RHOB | Low (approx. 2.68-2.8 g/cc) | Very High (2.8-3.15 g/cc) |
| NPHI | Low (0-0.06 v/v) | Low- High (silica-micaceous-chlorite rich) (0.03-0.3) |
| PEF | low PEF (approx. 2.5 B/E) | High PEF (4-6) |
| Resistivity | High (>1000 ohmm, low values in fractured/weathered zones) | High (>1000, low values in fractured/weathered zones) |

Table 1: well log characteristics for basement rocks identified in the study area.

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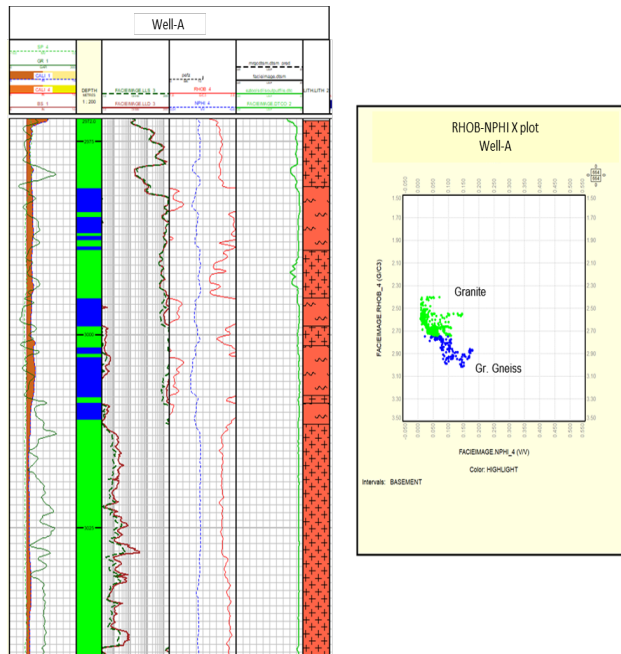


Fig 3. Granite and granite gneiss identified on the RHOB-NPHI cross plot and shown by green and blue color in the layout.

3. Identification of Efacies:

Basement rocks are unconventional in nature as they do not possess any primary porosity or permeability. A methodology has been designed and adopted to identify zones within basement that were either fractured and/or weathered and had porous and permeable character. Stepwise approach to identify such facies within basement on the basis of their capacity to hold and flow fluids was as follows:

- The first step in the process was to calculate a weathering scale. The weathering scale identified the weathered intervals within the basement along with the degree of weathering scale.
- The second step was to identify the permeable zones within the basement, which can either be fractured intervals or weathered permeable intervals having interconnected pores.

3.1 Weathering Scale Calculation

The term 'Weathering scale' is defined here as the degree to which the basement is weathered. It can be calculated using Eq. 1.

$$WEATH_{SCALE} = A - RD \quad (1)$$

Where, A= Average resistivity in the fresh massive basement zones

Weathering scale is plotted within a range of 0 to 1000 and intervals having a value greater than 400 are considered weathered zone here (track-7, Fig. 4).

3.2. Identification of Permeable Zones

The resistivity ratio given by Eq. 2 indicates the zones where invasion has taken place, indirectly indicates the permeable zones (Chaudhary et al., 2022),

$$RR = \frac{RD-RS}{RS} \quad (2)$$

Where,

RD= Deep Resistivity

RS= Shallow Resistivity

The above equation can be converted to a flag for better presentation using Eq. 3 and gives a clear idea about the presence of permeable zones in the drilled basement intervals.

$$RR_FLAG = GE(RR, 0) \quad (3)$$

The Permeable zones indicated by RR_FLAG are given in track-8 of Fig. 4.

3.3. Identification and classification of different facies within the basement

The above-mentioned 'weathered zones' and 'permeable zones' are integrated using the stepwise approach given below in Eqs-4 to 7 and the four facies are identified.

STEP-1:

$$IFC(AND(WEATH_SCALE \geq 400, RR_FLAG = 1), A, 0), \quad (4)$$

STEP-2:

$$IFC(AND(WEATH_SCALE \leq 400, RR_FLAG = 0), B, 0), \quad (5)$$



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STEP-3:

IFC(AND(WEATH_SCALE>=400,RR_FLAG==0),
C,0), (6)

STEP-4:

IFC(AND(WEATH_SCALE<=400,RR_FLAG==1),
D,0) (7)

Where, A=1=Blue= Permeable weathered Basement

B=2=Yellow= Fresh massive Basement

C=3=Orange=Non-permeable weathered
Basement

D=4= Green= Fractured fresh Basement

A & D (1 & 4) are reservoir facies having capacity for both, to hold and flow hydrocarbon. C (3) facies has porosity but no permeability and can be proposed for hydro fracturing. B (2) is fresh massive basement, which is neither fractured nor weathered and does not possess any reservoir properties. This facies can be discarded when evaluating the basement section for their hydrocarbon potential.

The weathered zones, permeable zones and the four identified facies are shown for wells B and C in Fig. 4.

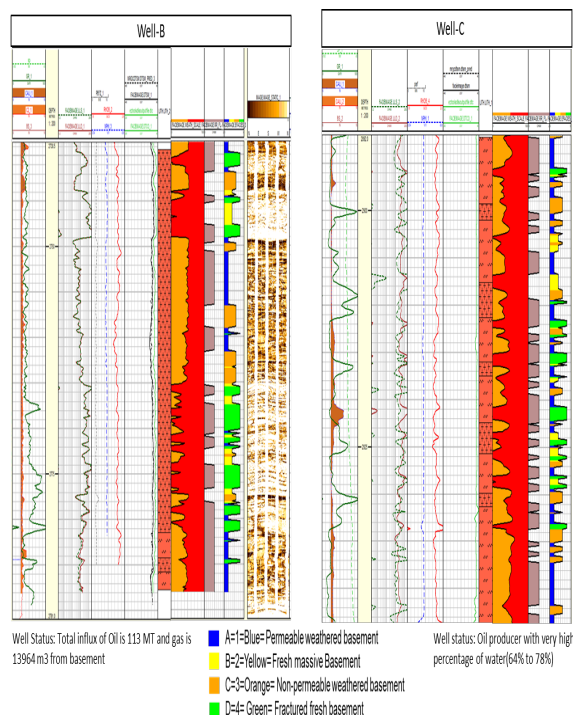


Fig 4. Layouts for wells B and C showing weathering scale (track 7), permeable zones (track 8), and identified facies (track 9).

4. Propagation of identified facies:

Three well profiles were prepared to understand the distribution of identified facies across the field. Profile-1 (Fig-5), which is the N-S well profile, starts from the well-H in the south and ends with well-D in the North of the study area. Well-H shows mostly massive fresh basement (Yellow) with no reservoir properties along with some fractured basement (Green), which has little porosity and permeability. The well showed no activation on testing. Well-G and -F have fractured (Green) and little weathered facies (Blue and Orange), both wells produced little oil on testing. However, well-E,-B and-G have the majority of weathered permeable along with non-permeable facies and have produced comparatively higher amounts of hydrocarbon from these wells.

It is to be noted that the identified facies give the reservoir quality of the drilled basement, and indicate whether the basement intervals have the capability to store any fluid, in this case, hydrocarbon. However, the interesting reservoir facies (Blue and Green) doesn't tell about the nature of the fluid present.

Similarly, Profile-2 (Fig-6) is prepared for wells along the E-W direction starting from well-I in the west and ending with well-M in the east of Borholla-Changpang field. The quality of the facies here can be correlated with the production data as shown in the figure. Wherever the permeable weathered (Blue) and fractured basement (Green) facies are present, the basement has produced hydrocarbon, in smaller amounts for mostly fractured basement facies, and higher production in wells having more of permeable weathered facies (Blue). The non-permeable weathered facies (Orange), has porosity but no permeability and can be considered for hydrofracturing jobs in hydrocarbon-bearing wells.

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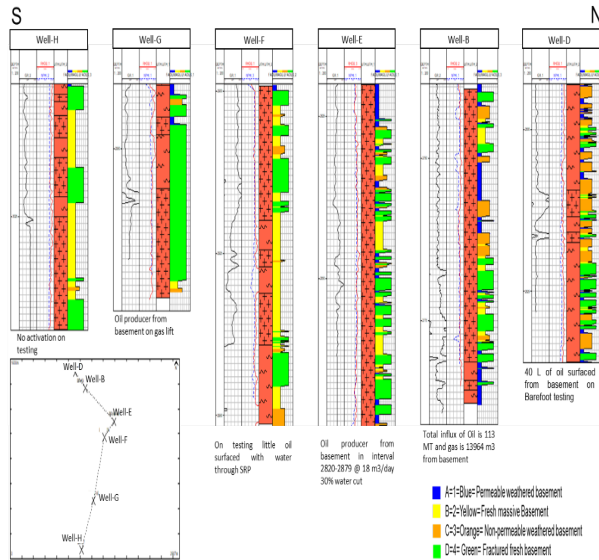


Fig 5. Wells along the N-S profile in the study area showing variation in the facies across the field.

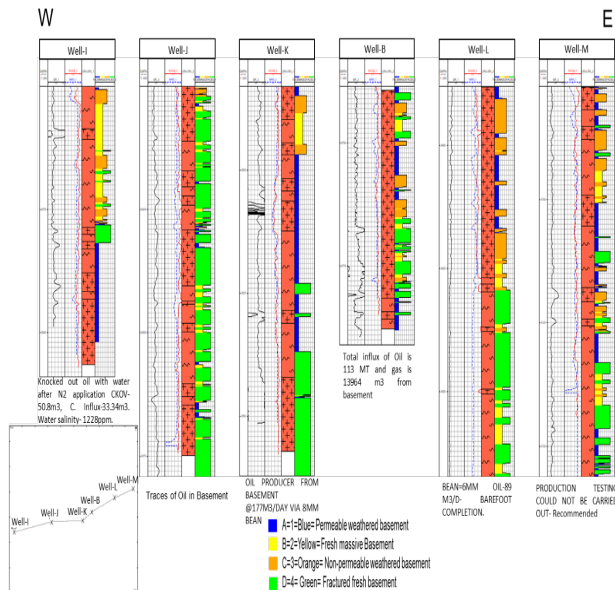


Fig 6. Wells along the E-W profile in the study area showing variation in the identified facies across the field.

Conclusion

This comprehensive study effectively evaluates the basement of the Borholla-Changpang field by integrating the well-log data and core studies. The detailed core studies provided petrophysical and reservoir properties of the basement. Log data analysis brought out two dominant lithologies within the basement of the Borholla-Changpang field, i.e., Granite at shallower intervals and granite gneiss along with granite in deeper intervals of the basement. The new methodology adopted helped in identifying the weathered/fractured and fresh massive basement zones within igneous and metamorphic basement rocks. Also on the basis of weathering scale and permeability zones, four facies (Permeable weathered basement, non-permeable weathered basement, fractured basement, massive basement) were identified. Image data analysis helped in validating the fractured and weathered zones.

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