5th Conference & Exposition on Petroleum Geophysics, Hyderabad-2004, India PP 106-110

An Innovative Approach for Formation Evaluation of Complex Panna Formation in Heera Field, Mumbai Offshore

Pardeep Kumar, Kamleshwar Rai, Sangeeta & R.P. Verma

Petrophysics Division, KDMIPE, ONGC, Dehradun

ABSTRACT : Multi-mineral model based upon statistical inverse modelling of well log data is best suited for complex reservoirs which contain an appreciable amount of basement rock fragments apart from the sand, silt, clay, feldspar, mica etc. The rock fragments are not pure minerals but a combination of various minerals like quartz, feldspar, mica, chlorite etc in varying proportions. Hence, it becomes very difficult to assign processing parameters for rock fragments in a multi-mineral model. In the present study, an innovative technique for selection of processing parameters of rock fragments in Panna formation of main Heera field, Mumbai offshore, has been evolved. These parameters have been selected from in-situ log data acquired against the weathered basement section of wells drilled on the crestal part of main Heera field i.e the source of rock fragments. The approach has been successfully applied for data processing of 16 wells of Heera field out of which the results for three wells from different parts of the field are presented in the paper. The results of the study corroborated well with the core data and initial production testing data. The developed methodology will be helpful in realistic formation evaluation during future exploration and development of Panna formation in Heera field. The study can be extended to other similar reservoirs of interest also.

INTRODUCTION

The Heera field situated about 75 km. south west of Mumbai city and 100 km. south east of Mumbai High field is one of the giant oil fields of Mumbai Offshore basin. The main producing formations are the Bassein limestone (B-zone) and Mukta limestone (A-zone) of Middle Eocene to Lower Oligocene and Lower Oligocene ages respectively. Both Heera and South Heera fields are hydrocarbon bearing in Panna Formation of Palaeocene to lower Eocene age also and commercial quantities of hydrocarbon are encountered. Recently two wells have shown a very good development of reservoir facies in Panna Formation and have been completed in this formation with oil production @ 1153 BOPD & 1803 BOPD respectively. Earlier also, six wells produced commercial quantities of oil from Panna formation during production testing.

The geological studies suggest that the crestal part of main Heera field remained high up-to lower Oligocene period which is confirmed by the absence of Bassein formation (B-zone) in the crestal part where Mukta formation(A-Zone) directly overlies Panna formation. The variation in thickness of Panna formation has been found to be in accordance with the depth of basement. The structure contour map at basement top (Plate-1) also indicates that there is a wide variation of the order of 200 m in basement top between the crestal part and the southern part where best reservoir facies have been encountered recently.

The sedimentological studies confirmed the dominant presence of rock fragments of basement in Panna formation in the northern part of the main Heera field. The rock fragments are also present in the southern part, though due to long transportation and diagenetic processes they appear to be altered into their constituent minerals like quartz, feldspar,

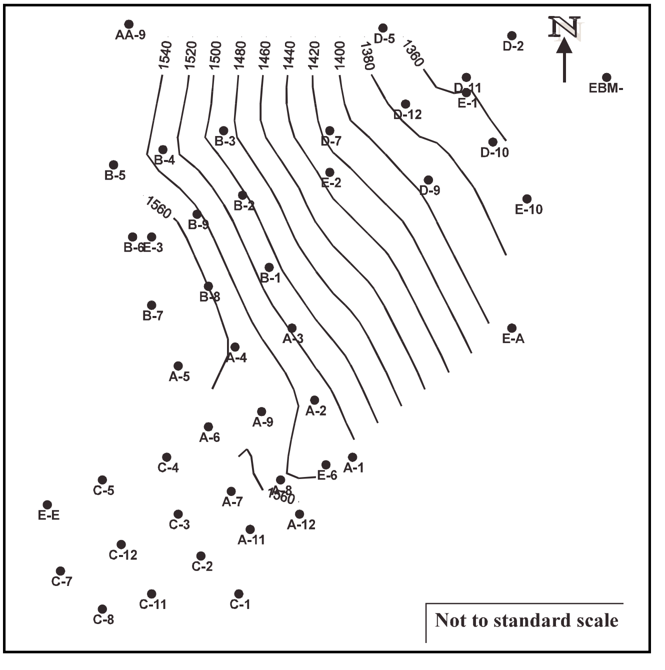


Plate 1 : Structure contour map at Basement top

mica, chlorite etc. to form better reservoir facies. So, there is every reason to believe that the rock fragments present in Panna formation are derived from the structurally higher basement in the crestal part. Dominance of chlorite as clay mineral further confirms the volcanic basement as source of rock fragments.

The presence of rock fragments, their constituent radioactive minerals and other heavy minerals make well log interpretation a challenging job in this area. Selection of processing parameters for rock fragments of weathered basement present in the reservoir rock is very difficult because they are not the pure minerals but a combination of quartz, feldspars, mica, chlorite etc. in varying proportions. These parameters are an essential input to the multi-mineral statistical model. An innovative approach for selection of processing parameters for rock fragments has been evolved. These parameters have been selected from in-situ log data recorded against drilled weathered basement sections in wells on the structurally higher crestal part of the field which is believed to be the source of these rock fragments.

The reservoir evaluation results along with environmentally corrected open hole logs for three wells D-10, A-12 & E-A located in the northern, southern and central part of main Heera field are presented in plates 3-5. These results corroborate well with the core studies and production testing data.

INTERPRETATION PROBLEMS VIS-À-VIS LOG RESPONSES

Panna formation has so far been explored in two areas of main Heera field viz. exploratory wells E-1, E-2, E-10 & D platform area in the northern part and exploratory well E-6 & A platform area in the southern part. The well log responses against Panna formation are quite different in the northern part & southern part of the field. Gross thickness of Panna formation in the northern part varies from 3 - 22 m., whereas in the southern part it varies from 17 - 50 m. The reservoir facies are better developed in the southern part than in the northern part of the field. Distinct coal streaks as well as influence of carbonaceous matter in the reservoir sections is observed in southern part where as dominance of heavy and radioactive rock fragments of basement rock is found in northern part.

Dominance of rock fragments in the northern part is conspicuous from gamma ray value in the reservoir section higher than that against overlying shale bed and also shale like separation on Neutron-Density log. Good development of SP wherever available indicates the intervals to have reservoir character. On testing such sections produced commercial quantities of oil. The presence of heavy & radioactive rock fragments make the interpretation with conventional shaly sand or textural model very difficult. In some of the wells of southern part the presence of heavy minerals is evident from high density (RHOB) & high Photoelectric factor (PEF). Without considering the influence of these heavy minerals the computed effective porosity and hydrocarbon saturation will be pessimistic.

METHODOLOGY

1. Identification of minerals present in the reservoir and shale section was done with sedimentological core studies on conventional cores, side wall cores and drill cuttings.
2. A mineralogical model was developed based upon the core studies and the available log suit as an input to the multi-mineral log interpretation model.
3. Petrophysical studies on core samples were carried out at Petrophysical Laboratory of KDMIPE, for Archie’s a,m,n parameters, porosity, permeability, grain/bulk density.
4. In house developed Multi-mineral log interpretation model ‘APTWEL” based upon inverse modelling statistical technique was used to process the well log data on SunSparc-20 workstation.
5. The processing parameters Density (RHOB), Neutron porosity (PHIN), Sonic Travel Time (DT), Gamma Ray (GR), Photo Electric Factor (PEF) etc. for rock fragments of basement rock present in reservoir facies have been selected from in-situ log data recorded against drilled basement sections in the structurally higher crestal part of the field (Plate-2).

The following mineral models were used based upon the sedimentological studies carried out in geological laboratories of KDMIPE (Annexure-I of Ref. 1), the earlier core studies (Ref.2&3) and availability of logs.

1. A five mineral model consisting of Quartz with calcitic cement as sandstone, rock fragments of weathered basement , mixed clay, mixture of pyrite, siderite & iron oxide as heavy mineral and coal were considered in the

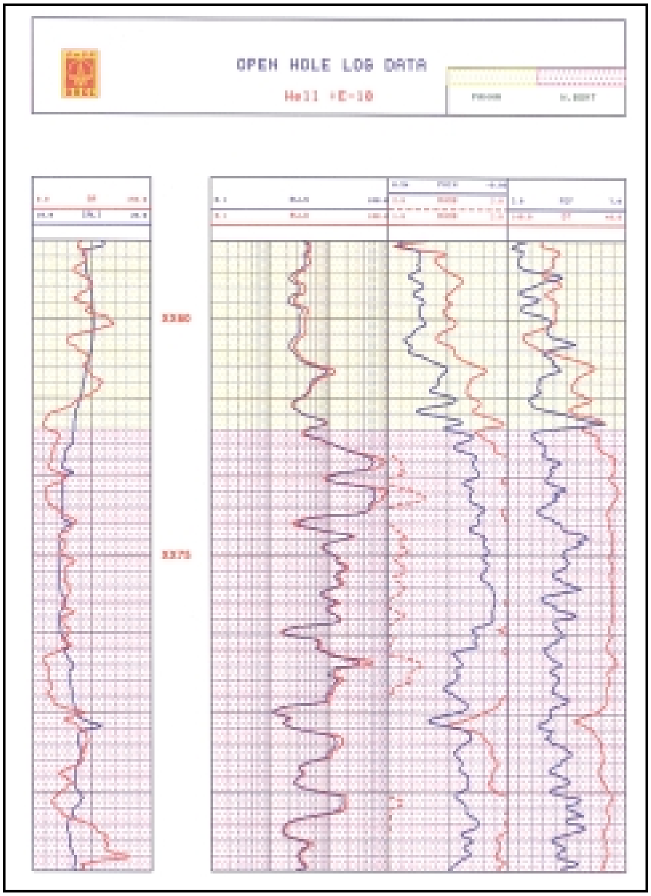


Plate 2

wells where sufficient log suit viz. RHOB, PHIN, DT, GR & PEF were available.

2. In the wells with 4 logs four mineral model consisting of quartz with calcitic cement as sandstone, rock fragments of weathered basement, mixed clay, mixture of pyrite, siderite & iron oxide as heavy mineral was considered. In these wells the top coaly layers were not included in the processing intervals where these layers do not appear to be prospective.

3. In the wells with only 3 logs viz. RHOB, PHIN & GR or the fourth log PEF severely affected by bad bore hole only three mineral model viz. Quartz with calcitic cement as sandstone, rock fragments of weathered basement, mixed clay has been used.

Laboratory determined petrophysical parameters, a=0.8, m=1.92 & n=1.72(Ref.4) and formation water resistivity of 0.12 @ 172 degree F has been used. The processing parameters for various minerals are detailed in Table.1

Table-1 Processing Parameters of Different Minerals used in Multimineral Model

Mineral	RHOB (gm/cc)	PHIN (p.u.)	DT (µsec/ft.)	UB= RHOB XPEF	GR (API)
Sandstone	2.68	-0.01	55	5.5-7.5	10-40
Rock Frag	2.8-3.0	0.12-0.2	50	12-17	50-300
Clay	2.42-2.6	0.42-0.52	105-115	12-13	50-100
Heavy Mineral	4.70	0.07	40	84	0
Coal	1.23-1.5	0.45-0.47	160	0.24 -0.32	5-10

DISCUSSION OF RESULTS

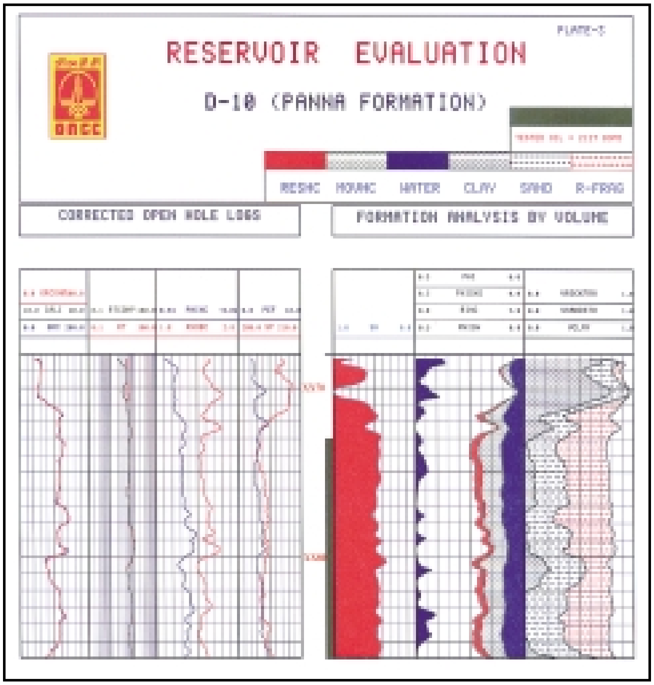
Well D-10

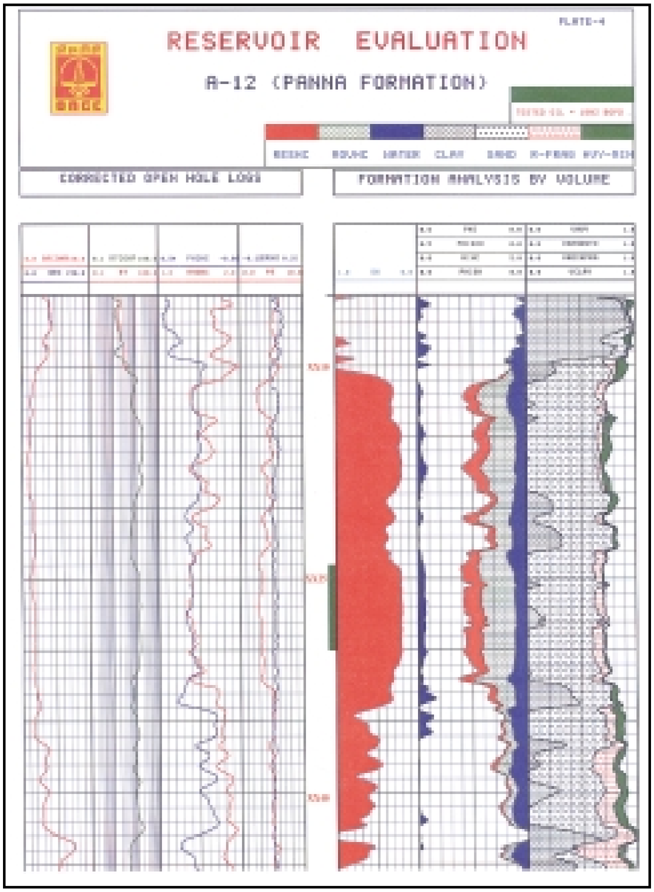
This is a deviated platform well located in the northern part of the field. In the interval XX71.5-86 m.(Plate-3), GR value varies from 80-140 API units in comparison to 60 API units against the overlying shale section. A positive Neutron-Density separation of 6-18 p.u. and the PEF between 3-5 units, along-with higher GR make the section look like highly shaly and rather non reservoir from the quick look. The negative SP development of the order of 10 mV suggests the section to be reservoir. This interval produced @ 2127 B/D of oil and 39,683 M^3/D gas during production testing.

Due to limitations of available log suite the data was processed with three minerals model as described above. The processed results (plate-3) suggest the section to be a reservoir dominantly composed of rock fragments as expected by the depositional model. The computed effective thickness, average effective porosity, Vclay & water saturation are 7.6 m, 21%, 8% and 45% respectively, suggesting the entire section to be hydrocarbon bearing. The results corroborate well with the production testing data. The depths on the plate are log measured depths and the effective thickness is in TVD depth.

Well A-12

This is also a deviated platform well located in the southern part of main Heera field and a very good development of reservoir facies is seen against the intervals XX11.0-13.5 m & XX23-32 m. (Plate-4).These layers appear to be clean sand having good porosity with PEF reading 2.5-3.0 units, low gamma ray, low RHOB and resistivity of 6-15 ohm m. The well on perforating in the interval XX26-30 m. produced oil @ 1803 BOPD. On the other hand the intervals XX14-23 m & XX33-46





m, PEF reads mostly 5 units with low to moderate GR, high RHOB, low PHIN and resistivity of 6-20 ohm m. These log responses suggest the intervals to be sandstone with presence of heavy minerals with low gamma ray like pyrite, iron oxide and siderite along with some rock fragments. These minerals have been reported in the core studies also (Ref.1).

The data was processed with four mineral model. The processed results (plate-4) show that the Panna formation in the interval XX11-45 m. is dominantly sandstone with rock fragments and heavy mineral with computed effective thickness, average effective porosity, Vclay & water saturation of 12.5 m, 23%, 5% and 29% respectively, suggesting the entire section to be hydrocarbon bearing. The results corroborate well with the production testing data.

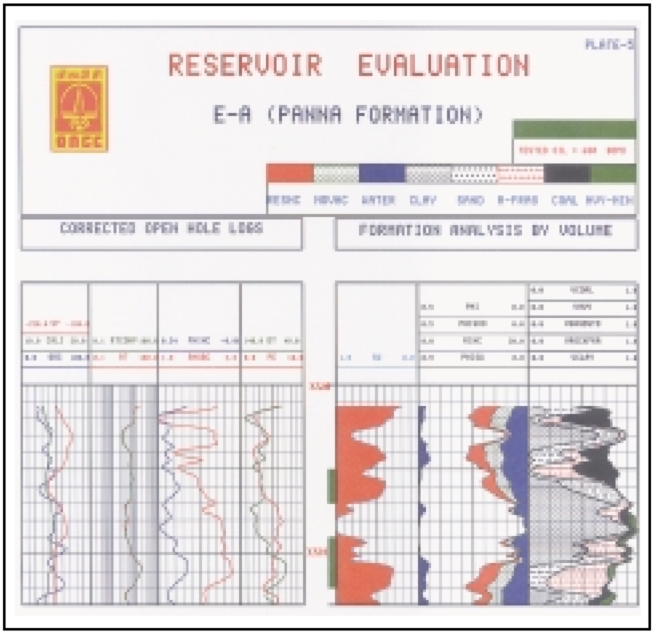
Well E-A

This is an exploratory well located in the central part of the field near the eastern flank. In this well Panna formation is not very well developed and contains coaly matter also in addition to quartz, rock fragments, clay and heavy minerals. This is the most difficult well to be processed even with a multi-mineral model. The perforated intervals XX05-07 and XX09-12 produced oil @ 680 BOPD. The data was processed with five mineral model as five lithological logs viz RHOB, PHIN, GR, PEF and DT were recorded. The processed results presented in Plate-5 show that the computed lithology is dominantly rock fragments along with coaly matter and heavy minerals. The computed effective thickness, average effective porosity, Vclay & water saturation are 3.7 m, 23%, 4% and 42% respectively, suggesting the section to be hydrocarbon bearing. The results corroborated well with the production testing data.

CONCLUSION

1. Gross lithology of reservoir facies in Panna formation is lithic/quartz wacke composed of quartz, rock fragments of granite & schist, heavy mineral like siderite, pyrite and iron oxide and clay minerals. Dominant clay minerals are chlorite, montmorillonite and illite.

2. The rock fragments present in the reservoir facies are derived from the weathered basement encountered structurally much higher in the crestal part of the main Heera field.



3. The best reservoir facies are encountered in the southern part of the main Heera field i.e. around wells E-6, A-11 & A-12 probably due to alteration of rock fragments into their constituent minerals and textural maturity gained due to longer transportation.

4. Presence of heavy and radioactive rock fragments and other heavy minerals make log interpretation with conventional shaly sand model very difficult and challenging task.

5. Multi-mineral interpretation model based upon inverse modelling statistical technique has been found best suited for formation evaluation of Panna formation.

6. Selection of processing parameters for rock fragments of weathered basement present in the reservoir rock is very difficult because they are not the pure minerals but a combination of quartz, feldspars, mica, chlorite etc. in varying proportions. These parameters are an essential input in multi-mineral model.

7. An innovative approach for selection of processing parameters for rock fragments has been evolved. These parameters have been selected from in-situ log data recorded against drilled weathered basement sections in wells on the structurally higher crestal part of the field. The methodology has been found very useful and can be adopted in such reservoirs.

8. The study will be helpful in realistic reservoir evaluation of Panna formation during future exploration and development of the field.

ACKNOWLEDGEMENTS

The authors express their gratitude to Dr. Debabrata Ray, ED-Head KDMIPE for his guidance, cooperation and providing all facilities to carry out the study. The authors are thankful to Sh. B.K. Sharma,GM(GRG), KDMIPE for his valuable suggestions and encouragement during completion of the study. The authors express their sincere thanks to Sh. S. Mohanty (C.G) & Dr. N. Pendkar (S.G.) of Geological Laboratory, KDMIPE for providing data on sedimentological studies. Thanks are due to Sh. J.P. Narayan, Dy.S.G.(W) for his help during preparation of the manuscript.

REFERENCES

Pardeep Kumar, sangeeta, April 2003, “ Formation Evaluation of Panna Formation in Heera Field of Mumbai Offshore”. Petrophysics Division, KDMIPE, Dehradun. ONGC Unpublished Report.

S.K. Karande, N.K. Lal & N.S. Khamesra, 1984, “Heera Field – Status of Exploration – A Review”, Development Geology Group, Bombay Offshore Project. ONGC Unpublished Report.

Malay Rudra et.al., May, 1986, “Core Analysis of Heera Well HB-9”, IRS, Ahmedabad, ONGC Unpublished Report.

Mohan Lal, R.M. Bahuguna, Nov.,2002, “ Petrophysical Studies on Core Samples of Panna Formation of Neelam & Heera Asset., Petrophysics Division, KDMIPE, Dehradun. ONGC Unpublished Report.