Establishing Connectivity Between Mukta and Bassein Formations of Bassein Field by Wire-line Formation Pressure Study

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Summary

Mukta and Bassein formations of Bassein field are believed to be separate reservoirs with a thin limestone-shale sequence in between acting as a barrier. However a considerable pressure drop in Mukta formation has been observed over these years, although there is no significant conscious production from this formation. On the other hand the pressure drop in Bassein formation is less than what is expected on the basis of material balance / simulation studies carried out by different agencies (with in-place of Bassein formation as 240 BCM). A better history match is achieved if the in-place of Mukta (34 BCM) is also added into the in-place of Bassein. This is a prima facie indication that these two reservoirs are not totally isolated, as believed hitherto, and there exists some communication between them.

The initial RFT pressures of these two reservoirs fall on the same gradient indicating there was no anomaly in the beginning. Later, with the commencement of production from Bassein formation in 1988, its pressure started depleting. This is reflected on the subsequent RFT plots as a lateral shift in the gradient without any change in slope. Now, with no significant production from Mukta, its gradient should have been the same. This, however, is not the case. Mukta formation is not only depleting, it is also showing a flowing gradient towards bottom, thus indicating a communication between Mukta and Bassein reservoirs. The first indication to this effect was noticed in 1994 when RFT pressures in Mukta and Bassein were recorded in some of the wells of a new platform BE. However it could not draw much attention because of insufficient pressure points in Mukta formation.

A major breakthrough in establishing connectivity between these two formations took place in 2001 when the RFT plot of Mukta in SB-10 with good number of pressure points showed an obvious flow gradient from top to bottom. This was further corroborated by the RFT plot of Mukta in well BC-10H (Pilot) in 2004.

There are a number of possible ways for this communication to take place, out of which the four major possibilities are: gas flow from behind the casing due to poor cement, chimneys in tight layer at some places or leaking shale bands due to their deposition near H_3B unconformity, gas movement along fault plane, and facie changes from shale to limestone in some part of the field. All these four appear to have played a role in establishing communication in our case.

Over these years RFT has been extensively used for reservoir pressure monitoring, formation fluid identification and permeability estimation, but to the best of our knowledge never been used for establishing connectivity between two reservoirs.

Introduction

Bassein field in Mumbai offshore, India is a giant gas field with 274 BCM of in-place reserves. The gas accumulation has taken place in two formations, namely Mukta and Bassein (formerly known as A and B zones) and their individual in-place reserves are 240 BCM and 34 BCM respectively. The reservoir characteristics of Bassein limestone is better than that of Mukta and therefore the field was developed in Bassein limestone. This formation is under production since 1988 and the cumulative gas production till date is to the tune of 130 BCM. There is no significant production from Mukta formation.

The two formations are separated by a thin tight limestone – shale alternation of thickness 10-12m. This alternation appears to be a perfect barrier between Mukta and Bassein limestone with almost nil effective porosity. Hence all the earlier reports rule out any connectivity between them.

During exploratory and initial development phase of this field RFT pressures were recorded in some of the wells. These pressures showed a common gas gradient between Mukta and Bassein. However, Bassein pressure started depleting with the commencement of gas production but there was no clue about Mukta pressure depletion since there was no gas production from this formation.

In 1994, when a new platform BE came up in the southern part of the field, RFT pressure tests were carried out in three of the wells. Surprisingly the Mukta formation of these wells showed a decline in pressure although there was no production from this formation. Two of these wells even showed a flowing gradient (reverse gradient) in Mukta formation indicating a vertical communication between Mukta and Bassein. At that time not much attention was paid to this anomaly, although it was the first indication of breach of the so called barrier between Mukta and Bassein. Later, one exploratory well BSE-1 drilled in 1997 also showed a depletion in pressure in Mukta but it lost significance because only two pressure points had been recorded in that section.

A major breakthrough in establishing the connectivity came in 2001 when the exploratory well SB-10 was drilled in the central part of the field. This time it did not leave any doubt as a good number of formation pressure points were recorded in Mukta. The pressure gradient shows that Mukta is not only depleted, it also has a downward flow gradient thus indicating a vertical movement of gas from Mukta to Bassein formation. Later one more well BC-10H (Pilot) drilled in 2004 corroborated the findings of SB-10.

Once the connectivity is accepted it is easy to explain why the actual pressure depletion trend is not matching with the material balance studies of Bassein formation with the in-place of 274 BCM. A performance analysis report on Bassein field by IOGPT in the year 2000 shows that a higher in-place of Bassein formation is required to match pressure-production history. The report has shown a better history match if Mukta in-place is added into Bassein. In other words Mukta and Bassein can now be considered as a single reservoir for all performance analysis purpose.

In the following paragraphs we will see how the RFT pressures looked like in the beginning of the field and later how they started depleting with production, with a particular emphasis on Mukta pressure. We will also discuss about the different possible ways of communication between these two formations.

The Tool

Wire-line Formation Pressure tool (i.e. RFT of M/s Schlumberger) is a widely accepted tool in logging industry for directly measuring formation pressures by inserting a probe into the formation and giving limited drawdown in order to suck the formation fluid. The formation pressures thus obtained may be plotted against depth to generate gradient of fluids present in the formation. A change in gradient within the reservoir indicates a change in fluid type. The technique is widely used to establish the fluid contacts. A later version of this tool is known as MDT wherein different modules such as down-hole fluid analyzer, pump-out, multi-probe, dual packer, PVT sampler, etc. have been introduced to facilitate better pressure measurement in low permeability formations, quality samples in invaded formations, real PVT samples for laboratory investigations, interference test, etc. In its simplest form MDT can be used as RFT to measure the formation pressure.

Observations

RFT has been extensively used in Bassein field over these years to monitor the formation pressure vis-à-vis the gas production. However pressures are not available in a number of wells in Mukta formation. Consequently our study is limited to only those wells were pressures in both the formations are available.

Fig -1 shows the pressure gradient of one of the early wells BA-3 drilled in 1986 (i.e. before the commencement of production from the field). As can be

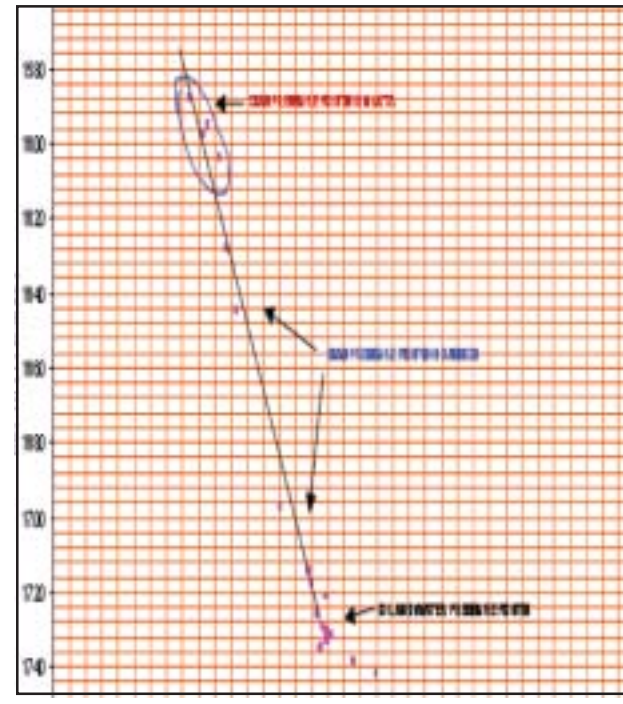

Fig. 1: RFT plot of well BA-3 in 1986, before the commenceent of gas production

seen, both Mukta and Bassein follow a common gas gradient, thus reiterating the fact that initially there was no pressure abnormality in these two formations.

Fig -2 shows the pressure gradients of wells BE-1 and BE-9 drilled in 1994. Although there was no direct production from this area at that time, the pressures recorded show depletion both in Bassein and Mukta formations. But whereas Bassein is simply showing a lateral shift in the gradient, Mukta is actually showing a change in gradient.

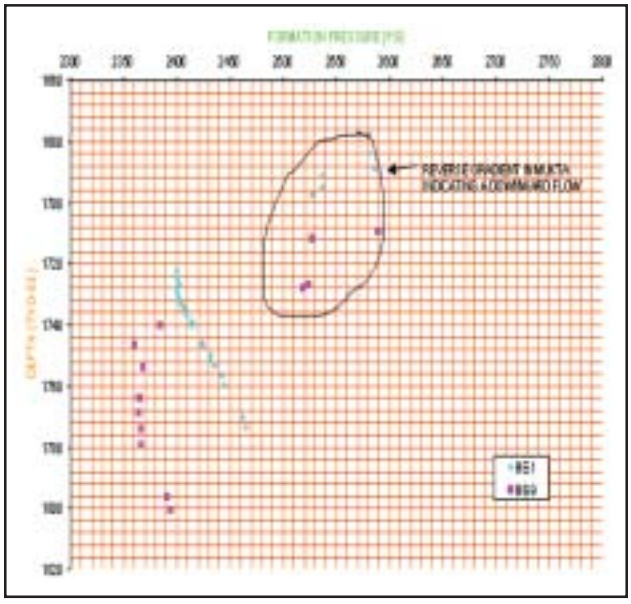

Fig.2: RFT plot of well BE-1 & BE-9 drilled in 1994, showing a reverse gradient in Mukta formation this indicating a downward flow.

The gradient can be seen to have taken a reverse shape which actually indicates a downward flowing gradient. Ironically this reverse gradient could not draw much attention because of insufficient pressure points in Mukta formation.

Fig-3 shows the pressure gradient of well BSE-1 drilled in 1997. This well also shows a shift in gradient in Bassein formation and a reverse gradient in Mukta formation. However, this reverse gradient cannot be given much credence as it is drawn on the basis of only two pressure points.

Fig-4 shows the pressure gradient of wells SB-10 and BC-10H (Pilot) which were drilled in 2001 and 2004 respectively. In both the wells the number of pressure points tested in Mukta was sufficient to draw any conclusion. Here again we can see a shift in gradient in the Bassein formation

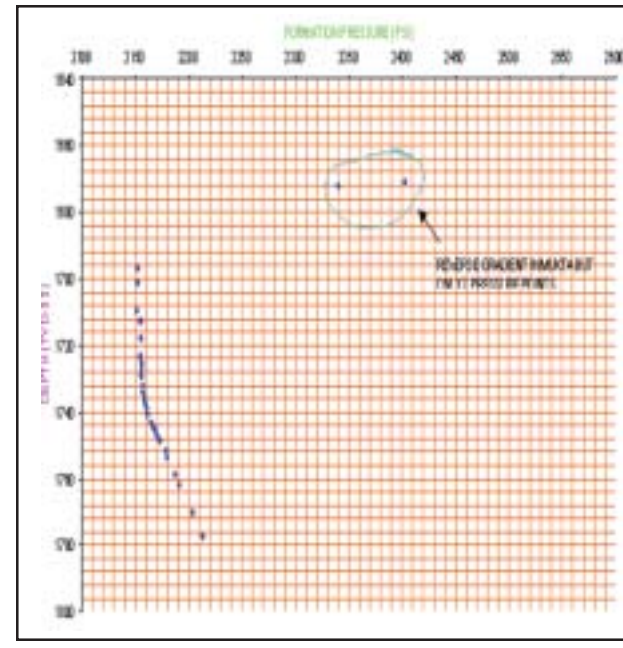

Fig.3: RFT plot of well BSE-1 in 1997, showing reverse gradient in Mukta formation but there were only two pressure points

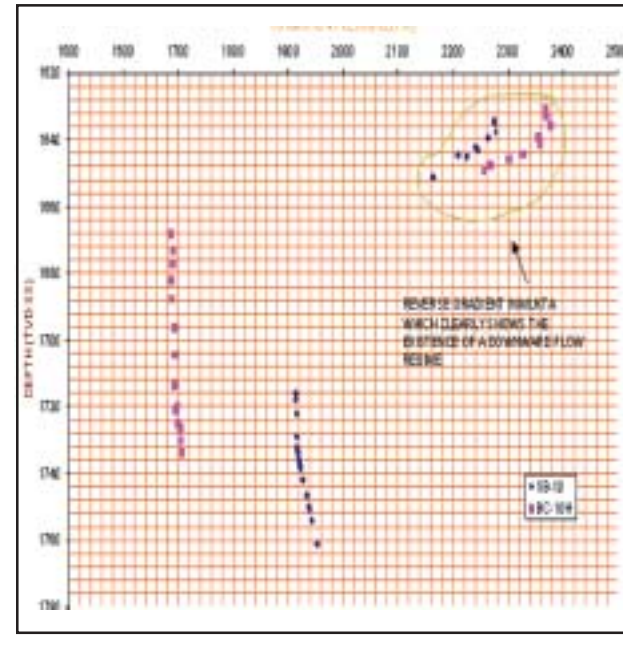

Fig.3: RFT plot of SB-10 in 2001 and BC-10H in 2004, clearly indicating a downward flow regime from Mukta formation.

and a conspicuous presence of flowing gradient in Mukta formation. The gradient undoubtedly establishes a vertical flow regime between Mukta and Bassein and also unfolds the mystery surrounding the history mismatch of Bassein formation.

Discussion

So far we have concentrated on establishing connectivity between Mukta and Bassein formations. Now we will discuss the ways this communication can take place. Although the shale-tight limestone alternations appear to be a perfect barrier between these two formations, change in facies at some places cannot be ruled out. Development of patchy porosity within the tight limestone has been reported in some of the wells of BB platform. This may well open a communication between these two formations. Secondly, the shale-tight limestone sequence is deposited just above H_3B unconformity which may lead to formation of chimneys in tight layers at some places. This may also result in leaking shale bands of 1 to 2m. These chimneys and leaking shale bands can play a role in establishing communication. The third possibility is the gas movement along the fault plane or from the periphery of the field. All these three possibilities have equal chances of occurrence but unfortunately there is no direct evidence to establish any of them.

The fourth and the only possibility which has got some direct evidence is gas flow from behind the casing. When the pressure of Bassein formation went below Mukta because of gas production from Bassein, the gas from Mukta may start oozing into Bassein from behind the casing. This is possible when cementation behind the casing is not good enough to isolate the zones. In the initial stage of development around 35 wells were drilled to exploit the Bassein gas. The cement bond logs of all these wells were studied to find out the possibility of channeling from behind the casing. It was found that 47% of these wells have poor bondage and 16% of them have moderate bondage while the rest 37% have a good bondage. This shows that gas flow from Mukta to Bassein from behind the casing is very likely. But this does not mean that the other possibilities have got less chances of occurrence. In our view all the possibilities are equally likely.

Conclusions & Recommendations

- Mukta and Bassein formations are in communication and the evidence of communication dates back to 1994 when formation pressures were recorded in the new wells of BE platform. However a clear picture emerged when wells SB-10 and BC-10H were drilled in 2001 and 2004 successively.
- Wire-line formation pressure clearly shows a reverse (downward flowing) gradient in the Mukta section of these wells.
- The evidence of communication is further corroborated by the fact that a better history match is achieved if in-place of Mukta is added up in the in-place of Bassein.
- Henceforth, Mukta in-place may be added into Bassein's in-place for all future field performance and simulation studies.

References

Performance Analysis of Bassein Field by IOGPT, Panvel (an internal report of ONGC)

An Overview of Bassein Field by S.Singh, et al (an unpublished report of ONGC)

Formation Evaluation Reports of Bassein field (internal reports of ONGC)

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