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Hydrocarbon prospectivity of Khubal Structure and it's adjoining area of Tripura Fold Belt - Some key issues

A.K.Jena*, B.S.Haldia, A.K.Sahoo, A.K.Bhanja & Asim Samanta

Summary

Gas discovery in Khubal structure in 2009 from a Lower Bhuban Sand of Lower Miocene age was a great news in the exploration history of eastern part of Tripura Fold Belt. The paysand produced gas at @ 1,54,474 m³/d through 8mm bean. After this discovery hopes are rekindled for the Geoscientists to step up exploration activities in eastern Tripura. This discovery is of great significance in eastern Tripura after a number of failures in structures like Hararganj, Langai, Lagntarai etc. There is an urgency in exploration/exploitation strategy due to ONGC's commitment for a steady supply of Gas to the downstream petroleum sector. From this study it could be inferred that this success is another story of synclinal exploration like eastern Sundalbari Syncline in western part of Tripura fold Belt. The entrapment of Gas in the Lower Bhuban Sand is a case of up-dip pinchout in western limb of Khubal Anticline and the sand continuing further down dip towards Champabari Syncline. The concealed northern plunge part along the axial region of Khubal structure is prospective from hydrocarbon point of view in comparison to the tectonically disturbed axial part towards south. Now it is more important to understand the entrapment model than just puncturing the anticlinal highs. The southern and eastern rising trend of the structure is prospective from hydrocarbon point of view but the entrapment model for the sand units should be understood properly. The sand units are found to be discrete in nature and look to be deposited as a complex system of stacked tidal bars/Channels with Mud flats. In well KH#D, the 52m producing Lower Bhuban sand pinches out towards KH#E and in KH#F, it becomes shaly. In KH#F it is structurally lower by 73m w.r.to KH#D. So a careful exploration strategy should be adopted to identify the vertico-lateral dispersal of discrete sands and their entrapment model. Petrophysical evaluation of sands is also a challenge due to bad hole conditions and paucity of good quality logs. So developing a proper petrophysical model will also guide in future for formation evaluation.

Keywords: Tripura Fold Belt

Introduction

Khubal structure lies in the eastern part of Tripura Fold Belt (Figure No 1,2&3). Khubal anticline lies between Jampai and Machhlithum Anticline. Deo syncline separates it from Jampai structure to the east. The structure is a doubly plunging, Anticline trending in NNE-SSW direction with abrupt separation from Sankhan anticline to south by a strike slip fault. The northern plunge of the structure is relatively wide and well marked, but the southern plunge is short and abruptly truncated. The structure is about 30km long and 15km wide. Two structure building longitudinal reverse faults are well marked. The Champabari Syncline separates it from Hararganj Anticline towards west. The Champabari syncline is narrow towards south where as it takes a turn and almost aligns with the plunge axis of Khubal Anticline towards North and becomes wider. Khubal structure got prominence in 2009 when a Lower Bhuban Sand of Lower

Miocene age produced gas at @ 1,54,474 m³/d through 8mm bean. This discovery is of great significance in eastern Tripura after a number of failures in structures like Hararganj, Langai, Lagntarai etc. In Khubal structure also there is no significant success after KH#D. In southern part of the structure, KH#A KH#B and KH#C in structurally higher position close to anticlinal axis were found dry. In recent past also KH#E & KH#F have gone dry except minor non commercial gas production from KH#E. By the time of writing this paper two wells KH#H & KH#I were under drilling and KH#G was kept aside for testing after drilling completion. So the question arises what happened to the 52m thick paysand of KH#D? It can be noted that the sand pinches out in SE direction in KH#F within 1000m. In this study an attempt has been made to find some plausible answers to the failures in exploration pursuits and the way forward. The objective of the study was to establish correlative signature of the sand units of Bokabil, Upper Bhuban and Lower Bhuban formations in



Khupal and adjoining area. Understanding depositional regime of Bokabil, Upper Bhuban and Lower Bhuban formations in Khupal and adjoining area.

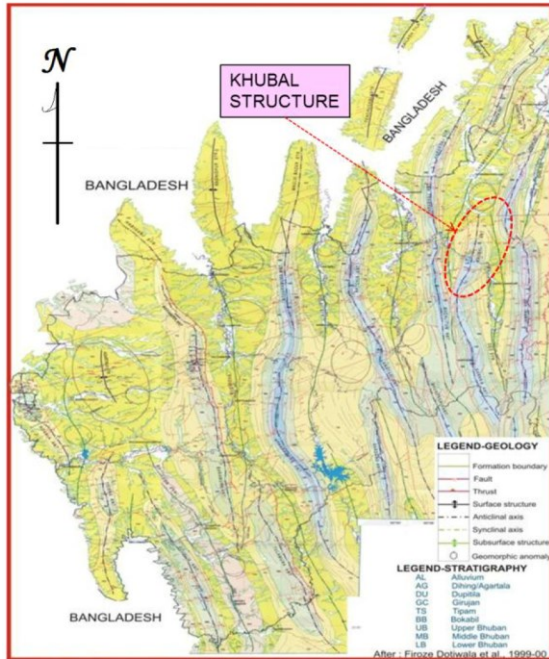


Figure No:1 Geological Map of Tripura

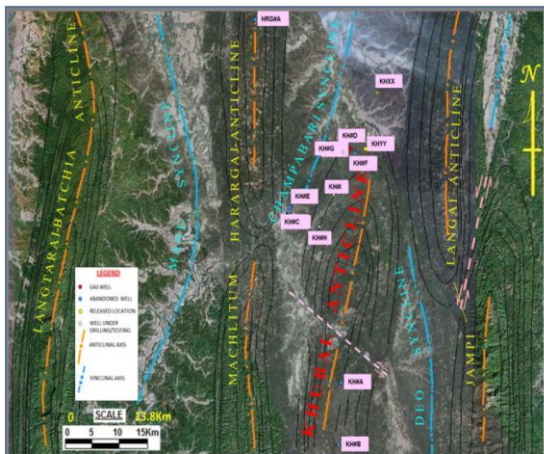


Figure No:2 Satellite Image showing Khupal Structure and adjoining Area

Understanding depositional regime of Bokabil, Upper Bhuban and Lower Bhuban Formations, Petrophysical evaluation of the hydrocarbon bearing sand units and identification of prospective areas from Hydrocarbon point of view.

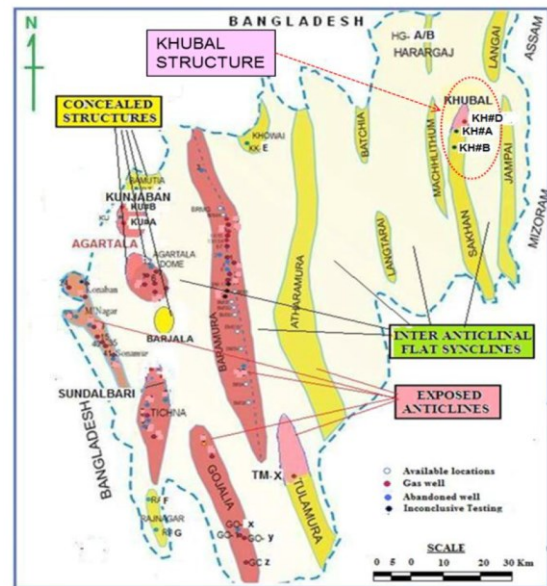


Figure No:3 Map showing structures of Tripura

Geological Setting & Stratigraphy

Khupal structure lies in the eastern part of Tripura Fold Belt (Figure No 1,2&3). Khupal anticline is towards east of Hararganj and Machhlithum Anticline. Jampai and Langai Anticlines are situated towards east of Khupal Anticline. Deo syncline separates it from Jampai Anticline towards east. The structure is a doubly plunging, Anticline trending in NNE-SSW direction with abrupt separation from Sankhan anticline to south by a strike slip fault. The northern plunge of the anticline is broad and well marked, but the southern plunge is short and abruptly truncated. The structure is about 30km long and 15km wide. Two structure building longitudinal reverse faults are well marked. The Campabari Syncline separates it from Hararganj Anticline towards west. The Champabari syncline is narrow towards south where as it takes a turn and almost aligns with the plunge axis of Khupal Anticline towards North and becomes wider. Khupal Anticline exposes about 1900m of Neogene clastics. The oldest formation exposed in the core of the Anticline is Upper Bhuban formation flanked by Bokabil and Tipam Formations. The Upper Bhubans are exposed towards Southern eroded part of the Anticline whereas Bokabil, Tipams towards southern plunge part.



CHRONOSTRATIGRAPHY		LITHOSTRATIGRAPHY		GENERALISED LITHOLOGY	THICKNESS (m)*	DEPOSITIONAL ENVIRONMENT	REMARKS	
QUATERNARY	AGE	GROUP	FORMATION/MEMBER					
	RECENT TO PLEISTOCENE			ALLUVIUM	Loose sands, silts and clays		Fluvial	Present in Northern part. Eroded in central part
			DIHING	Pebble beds, conglomerates and sandstones with thin beds of clay				
***** U N C O N F O R M I T Y *****								
NEOGENE	PLIOCENE	DUPITALA	UPPER	Coarse, pebbly sandstone & mottled clays		Fluvial	Present in Northern part. Eroded in central part	
			LOWER					
	***** U N C O N F O R M I T Y *****							
	MIO-PLIOCENE	TIPAM	GOBINDPUR	Variated soft & sticky clays often silty with Sandstone			Fluvial	Exposed Present in Northern part. Eroded in central part
			JAIPUR	Mainly sandstone with clays and claystone.				
	MIOCENE	SURMA	BOKABIL	Alternate layers of sandstone / siltstone and shale with subordinate claystone	600-700	Brakish/Shallow Marine	Exposed in central part	
UPPER BHUBAN			Shale with alternate sandstone/siltstone beds.	500-550		Exposed in south central part		
MIDDLE BHUBAN			Thick beds of shale with siltstone and sandstone alternations.	1000-1200	Outer shelf/Shallow Marine	Fully penetrated		
LOWER BHUBAN			Alterations of sandstone and shale		Brakish/Marginal Marine	Partially penetrated		
***** U N C O N F O R M I T Y *****								
PALAEOGENE	OLIGOCENE TO LATE EOCENE	BARAIL	RENJI	Dominantly sandstone with thin shale layers		Brakish/Marginal Marine	Not penetrated	
			JENAM	Shale and occasional sandstone				
			LAISONG	Alterations of thin sandstone and shale beds				
	EOCENE	DISHANG	DISHANG	Dark grey shale with thin beds of sandstone				

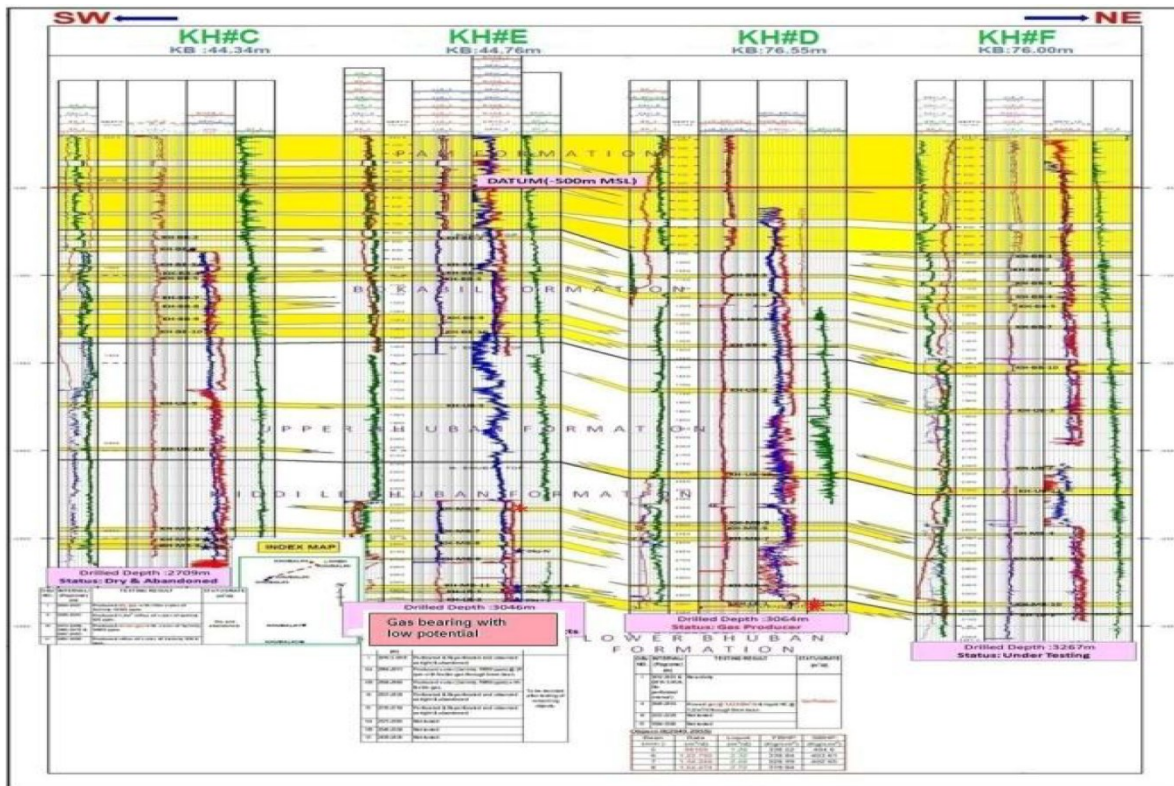


Figure No: 4 Structural Correlation along wells KH#C, KH#E, KH#D & KH#F



The cross faults have shifted the anticlinal axis as evident from photogeological maps. The generalized stratigraphy of Khubal structure and adjoining areas is given in earlier part of this paper.

Sand Geometry & Depositional Setup

In Khubal area the penetrated sediments consists of Lower, Middle, Upper Bhuban, Bokabil and Tipam and post Tipam sediments. Upper Bhuban and Bokabils are exposed in southern part of Khubal Structure where as Tipams are exposed in the northern plunge part. But in most of the wells only part of Lower Bhuban has been penetrated. It can be observed in correlation profiles(Figure No:4) in the study area that lithologically Upper Bhuban and partially penetrated Lower Bhubans are more argillaceous, where as Middle Bhuban is more arenaceous. Bokabil is represented by massive sand units with intervening shale/claystone bands. Tipams consist of massive fresh water sand units with thin intervening claystone/shale units. Partially penetrated Lower Bhubans are characterised by alternating Sandstone/siltstone and silty shales with major shale sections with more regressive phases. The gas producing blocky massive sand unit of 52m thickness of Lower Bhuban formation has been named as KH-LB-1 as per this study. The log motif of this sand shows a parallel combination of Resistivity, Gamma Ray and Neutron-Density curves (Figure No:7c).The massive sand unit almost pinches out in KH#F towards SE direction. Similarly it pinches out in KH#F, KH#E & KH#A towards west and south west direction. About 45m of the equivalent sand is observed in well KH#G towards west of well KH#D (Figure No:6b) However it becomes more shaly in this well. From the Master Log of KH#D (Figure No:5) it can be observed that it has angular to sub angular, poorly to moderately sorted quartz grains suggestive of a closer provenance. The dispersal pattern of the sand unit is depicted in Figure No:6a which suggests the sand unit to be a combination of stacked tidal channels and bars elongated in NNE-SSW direction in a shallow marine condition. The tidal channels and bars/ridges have mud flats inbetween with active and abandoned channels resulting in highly laminated fine grained sandstone/siltstone/shale alternations. The cleaner portion of the channels/bars form excellent reservoirs as in case of the producing blocky sandstone of KH-LB-1 of well KH#D. The more cleaner portions are close to channel/bar axis.

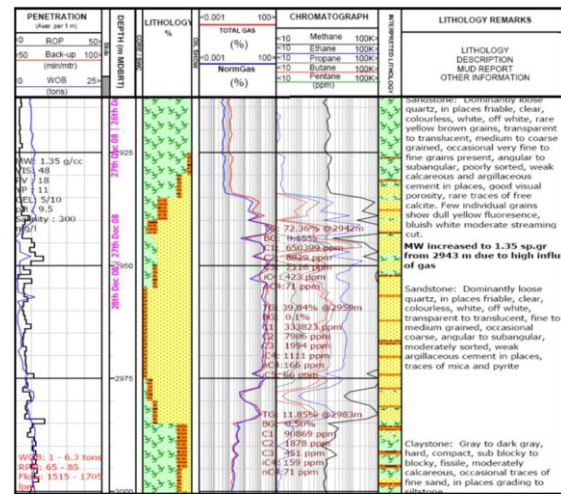


Figure No:5 Part of Master log of KH#D depicting KH-LB-1 Sand of Lower Bhuban Formation

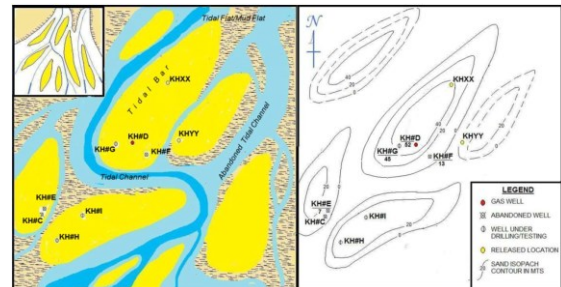


Figure No: 6(a) Possible depositional regime of KH-LB-1paysand (b) Sand isopach Map of KH-LB-1paysand

For petrophysical evaluation of lower Bhuban sands only well specific R_w values have been used. Dual water model has been used for saturation computation and accordingly petrophysical parameters $\alpha=1$, $\alpha=2$ and α is related to average porosity which turned out to be $mDWA=1.99$ to 2.0 were used for processing of log data. The cross plots are given in Figure Nos: 7a & 7b. The processed output of gas producing KH-LB-1 paysand in well KH#D has been depicted in Figure No:7c

Structure and Entrapment

To understand structure and entrapment in Khubal Structure, Geological map, formation tops from logs and relatively good quality 2D seismic lines were studied in this area to bring out the structure and entrapment model. In 2D seismic line X-X' (Figure Nos:8a & 8b) It can be observed in this EW dip line that F3 and F4 are the structure building reverse faults and the anticlinal feature is visible between SP-800 to SP-1100. The reverse faults



F2 and F3 to the west bound the rising eastern flank of Hararganj anticline further west. The syncline between F2 and F3 is quite narrow. KH#D lies at SP-840 on this line. It can be observed that the producing lower Bhuban sand KH-LB-1 is in the rising western flank of Khubal anticline. The strike slip fault CF2 cuts across the structure which can be observed in break in reflection patterns and abrupt change in continuous seismic signature patterns visible between SP-920 to 930 in Lower and Middle Bhuban sections. The rising trend towards Langai Anticline is clearly visible between SP-1090 to 1150 Bhuban and Post Bhuban sections. This high trend towards east is separated by a narrow syncline in between. The rising trend towards east is prospective from HC point of view with up-dip pinch out situations. In Seismo- Geological section along dip line 'X-X' between SP-450- 1160 has been prepared (Figure No:8b). Khubal structure is bound by F3 and F4 is clearly depicted. Champabari Syncline between Khubal and Hararganj anticline is clearly depicted. The rising trend towards west is actually a part of eastern flank of Hararganj Anticline. Here it can be observed that part of Lower Bhuban formation has been penetrated by KH#D but Tipam and post Tipam sediments are exposed. Champabari Syncline between Khubal and Hararganj anticline is clearly depicted. The major observation is that the anticlinal axis of Khubal structure has slightly shifted towards east by CF2 which is visible in strike seismic lines. This shifting has caused KH#F about 73m down with respect to KH#D at Lower Bhuban top level. After integrating seismic, log and geological data, it time to come out with a plausible structural model and explain the possible entrapment model in the study area. The

adopted fault pattern has been taken from earlier studies with slight modification as and when required based on the visible faults in seismic sections and log data of recently drilled wells particularly KH#E and KH#F. Four structure building longitudinal faults F1, F2, F3 and F4 are depicted. F1 and F2 affect the eastern-most flank of Hararganj Anticline, while F3 and F4 are the structure building longitudinal faults for Khubal Anticline. Part of Khubal Anticline particularly towards Northern plunge part which has been dissected by three strike slip faults CF1, CF2 and CF3. CF3 being the northern most, CF2 in the central part and CF3 towards the south. CF1 is dextral and CF2 and CF3 are sinistral in nature. The strike slip fault CF2 which dissects Khubal structure between KH#D and KH#F has moved anticlinal axis towards east in southern side (Side of KH#F) which is responsible for bringing down KH#F by about 73m, 95m and 76m with respect to KH#D at lower Bhuban, Middle Bhuban and Upper Bhuban top levels respectively. Structure contour Map at top of Lower Bhuban Formation is given in Figure No:9. At lower Bhuban top level, KH#D is structurally down by 695m and 58m w.r.to KH#A and KH#E respectively, where as it is up by 73m w.r.to KH#E. At Lower Bhuban top level KH#G is down by 33m w.r.to KH#D. So the producing sand which is 52m thick in KH#D and 45m thick in KH#G is a clear case of Synclinal stratigraphic trap because it is hydrocarbon bearing in KH#G also. There is a narrow low towards east of released location KHYY and further east a rising trend continues which may be prospective from HC point of view. So far no success has been tasted in western rising flank towards Hararganj Anticline from commercial hydrocarbon discovery point of view. But the rising trend

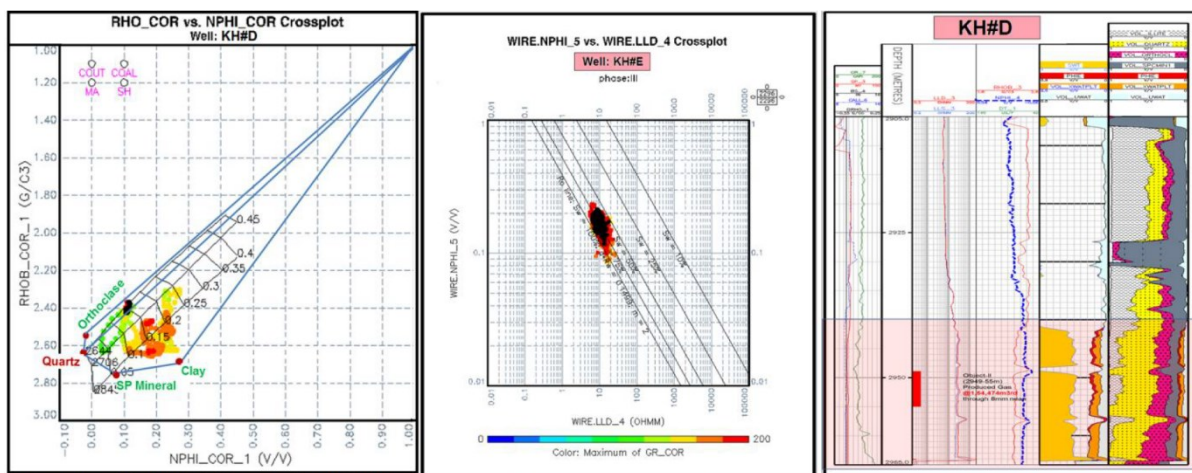


Figure No:7 (a) RHOB-NPHI cross plot of KH#D

(b) NPHI-LLD Crossplot of KH#E

(c) Processed output of KH-LB-1 sands in KH#D



towards east w.r.to KH#E looks to be prospective if KH-LB-1 and KH- MB-10 sands are encountered.

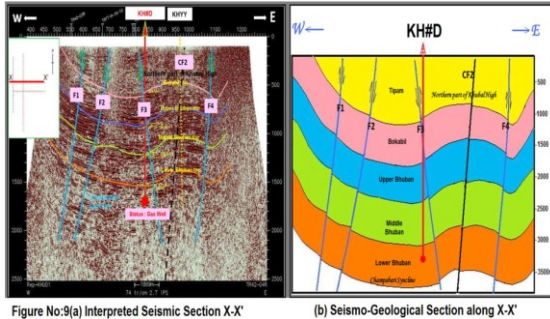


Figure No:9(a) Interpreted Seismic Section X-X' (b) Seismo-Geological Section along X-X'

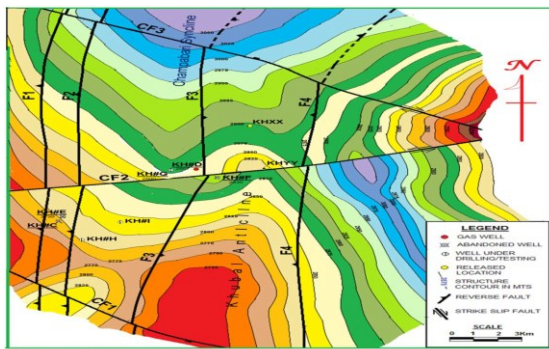


Figure No:10 Structure Contour Map at top of Lower Bhuban Formation

Conclusions

- From Geological and petrophysical observations the Lower Bhuban & Middle Bhuban sand units look to deposited as combination of stacked tidal channels and bars where as Upper Bhuban sand units are deposited in more regressive phase with marine incursions. Sand units of Bokabil formation look to be deposited as stacked distributary mouth bars and distributary channels where as Tipams consist of massive fresh water sand units of stacked braided bars and channels of river systems.
- In Khubal Structure,wells have gone dry with structural advantage and show complex sand dispersal pattern. So a careful exploration strategy should be adopted to identify the vertico-lateral dispersal of discrete sands and their entrapment model rather than puncturing anticlinal highs.
- The concealed northern plunge part along the axial region of Khubal structure is prospective from hydrocarbon point of view with likely undisturbed closure in plunge region for

Bhubans, particularly Lower and Middle Bhuban formations.

- The southern and eastern rising trend of Khubal anticline is prospective from hydrocarbon point of view. Identification of entrapment in arenaceous units has to be further narrowed down.
- The Champabari Syncline and the Geomorphic anomaly in Northern part Khubal Structure should be taken for Synclinal exploration for stratigraphic traps after success in KH#D with suitable entrapment condition.

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