Analysis of coal effect on seismic amplitude and its implication on fluid and lithology prediction

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Summary

This is an investigation to analyze the effect of coal sequence on seismic amplitude. The Barail Coal Shale (BCS) sequence sands of Barail Group of Oligocene age are the main pay sands of Laplinggaon area. It was observed though the coal percentage is not varying much throughout the area, there is a large variation of average absolute amplitudes. The reasons behind this are investigated in this paper through post-stack modeling. Further investigation was also done through pre-stack modeling to assess whether fluid effects were detectable on the far-offset amplitudes within coal sequences. Also with the use of near average absolute amplitude and far amplitude, a fluid indicator attribute has been derived. The results indicated that all three factors i.e. coal proportion, number of coal layers and relative disposition of thick and thin layers within the sequence contribute to seismic amplitude variations. The higher the near average absolute amplitude, the more likely it is to have higher coal content, while increasing far amplitude means a higher likelihood of oil/gas occurrences, for low coal percentage.

Introduction

The study area, of nearly 136 Sq. Km, lies in Laiplinggaon area of Assam and Assam Arakan basin (fig.1). Laiplinggaon is a recent field (2005) compared to other fields in this part of the basin. It is an independent structure lying in the north of main Lakwa-Lakhmani field. The BCS sands of Barail Group of Oligocene age, known as LBS pays, are the main pay sands (LBS1 to LBS6). Among these pay sands, LBS1 &2 are quite extensive while LBS5 is also widely developed. These three sands are the main producing reservoir contributing in almost equal proportions to the daily production from Laiplinggaon. LBS6 is interpreted as gas bearing sand while the rest two sands, LBS3&4 are discrete in nature and have sporadic hydrocarbon occurrences. It is widely believed that high amplitude coal reflectors are capable of leaving some sort of imprint on seismic data sets, within and below BCS sequence hindering characterization of the pay sands therein.

Methodology

Net to gross coal percentage were calculated for BCS sequence for all the wells (fig.2). Average absolute amplitude (AAA) map estimated from near offset (0-2000m) stack was generated in the zone of interest i.e. BCS top to LBS1 top (fig.3). Examination of two maps, coal percentage & AAA, show anomalous behavior in the sense that coal percentage is not varying much throughout the area but there is a large variation of average absolute amplitude as revealed in the maps. The reason for this was analyzed through post-stack modeling. In this approach one more investigation was done through pre-stack modeling to assess whether fluid effects were detectable on the far offset amplitudes in coal sequences or not. The workflow devised for this study is shown in fig.4.

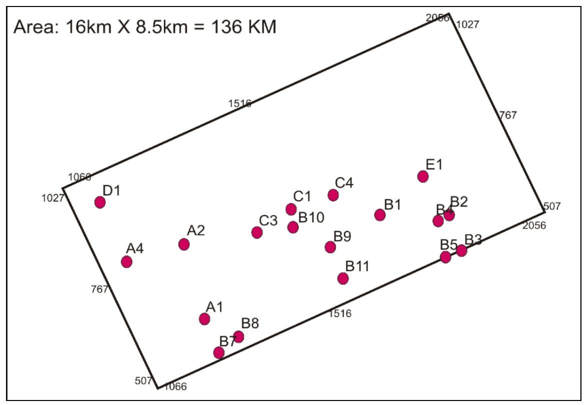

Fig.1: Base map showing the area of interest, geometry and the wells used in the study.

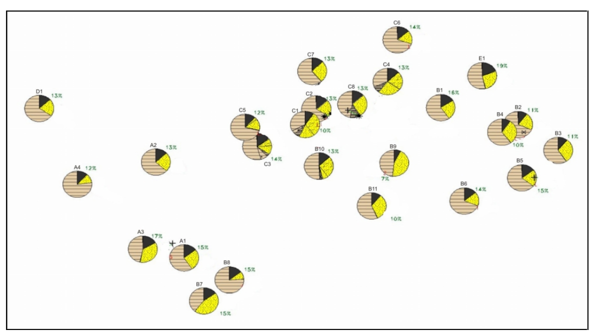

Fig.2: Pie-chart map showing the coal percentage (black) in each well derived from well logs.

Post-Stack Modeling

For uniformity in calculation of net to gross coal percentage in the wells, BCS to BCS+160m thick column (fig.5) was chosen for all the wells where coal concentration is consistent. In the above defined zone, the

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percentage of coal calculated for each well then all wells are classified on the basis of coal percentages (table-1).

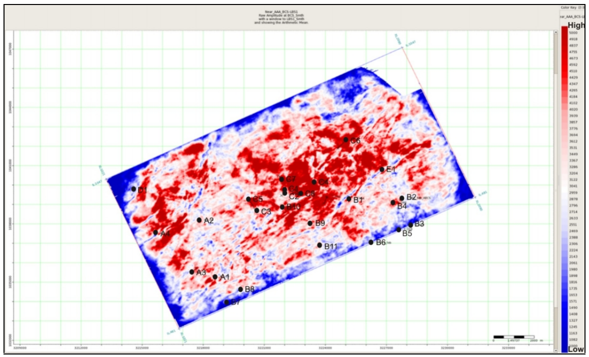

Fig.3: Average absolute amplitude (AAA) map from near offset (0-2000m) stack within zone of BCS to LBS1.

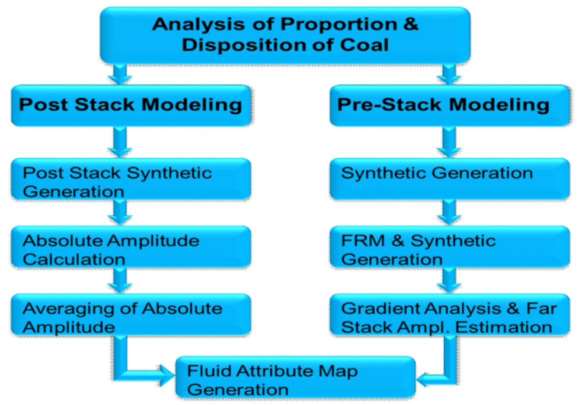

Fig.4: Work-flow devised for this study.

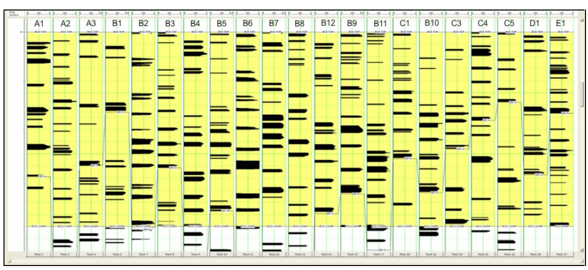

Fig.5: Vcoal log of wells (flattened at BCS top) showing the coal content; highlighted (yellow) zone between tops BCS to BCS+160m used in post-stack modeling.

The numbers of coal layers are also calculated in each well. Now having the coal percentage and number of layers, post-stack modeling was done to see the effect of this on seismic amplitude. For that post-stack synthetic trace was generated then this trace was converted to absolute amplitude trace from which average absolute amplitude (AAA) was calculated. After post-stack modeling, AAA between BCS to BCS+160m for each well was calculated and values were updated in the table-2. The graphical representations of the above tabulated results are revealing interesting facts which are shown in fig.6. It is found that AAA is increasing as the coal percentage is increasing but it is decreasing as the number of coal layer is increasing.

Coal%	11%	14%	15%	16%	17%	18%	20%	22%
Wells	A2 (12)	C1 (16)	A2 (19)	B3 (18)	B8 (14)	B11 (15)	E1 (23)	B4 (14)
(Coal-layers)	B1 (10)	B10 (12)	B5 (16)			C4 (15)	B9 (16)	B6 (13)
		C3 (12)				B2 (14)		B7 (13)
						A1 (12)		

Table.1: Classification of wells on the basis of coal percentage along with number of coal layers within analysis window (BCS to BCS+160m) in each well.

Coal%	11%	14%	15%	16%	17%	18%	20%	22%
Wells (Coal-layers) (AAA)	A2 (12) (0.14)	C1 (16) (0.10)	A2 (19) (0.10)	B3 (18) (0.27)	B8 (14) (0.23)	B11 (15) (0.19)	E1 (23) (0.21)	B4 (14) (0.32)
	B1 (10) (0.21)	B10 (12) (0.12)	B5 (16) (0.12)			C4 (15) (0.16)	B9 (16) (0.30)	B6 (13) (0.13)
		C3 (12) (0.18)				B2 (14) (0.15)		B7 (13) (0.22)
						A1 (12) (0.28)		

Table.2: Values of AAA, calculated for each well given in the table.1 for same analysis window.

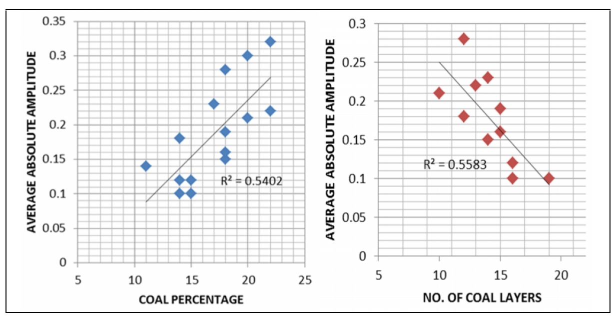

Fig.6: Variation of AAA with coal percentage (left) and number of coal layers (right).

There is one more possibility that percentage and number of coal layers may be same but layer thickness may vary. So, it was decided to understand the effect of thickness and distribution of coal layers on amplitude keeping coal percentage and layers same. Synthetic scenarios were created at well A4. In this well, between tops BCS to BMS having total thickness of 280m, the coal proportion was kept constant i.e. 10 % (28 m) and number of coal layers also kept fixed to 4 but with different thickness distributions as given below:

- Scenario-1: 2-3-3-20 m
- Scenario-2: 2-2-12-12 m
- Scenario-3: 1-8-9-10 m

Using the above scenario, synthetic traces were generated and average absolute amplitudes were calculated (fig.7). Results show that combination of more number of thick and less number of thin layers of coal gives rise to relatively higher AAA and vice versa.

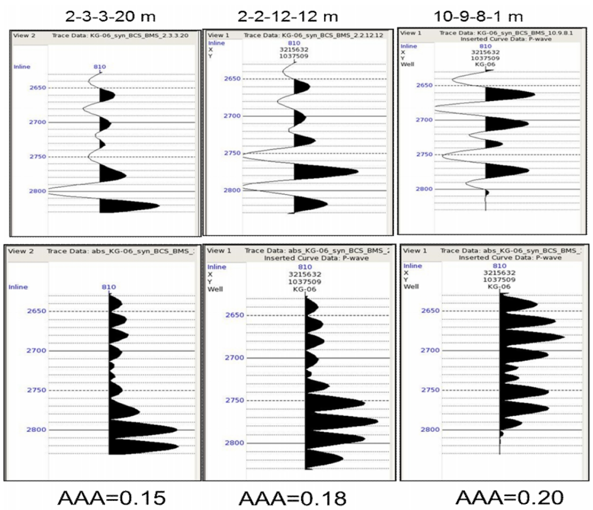

Fig.7: Modeled traces and corresponding AAA values calculated for given scenarios-1, 2 & 3.

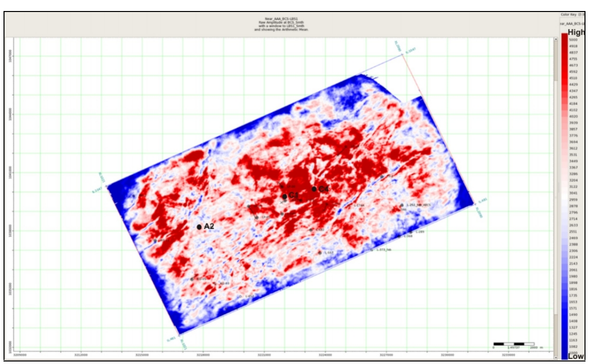

Fig.8: AAA map as shown in fig.3 along with wells A2, C1 and C4 used in analyses.

Observations indicate that all three factors i.e. coal proportion, number of coal layers and relative disposition of thick and thin layers within sequence contribute to seismic amplitude. This implies that seismic amplitude based study for geological feature identification in coal dominated sequence will always be influenced by these effects from coal laminations.

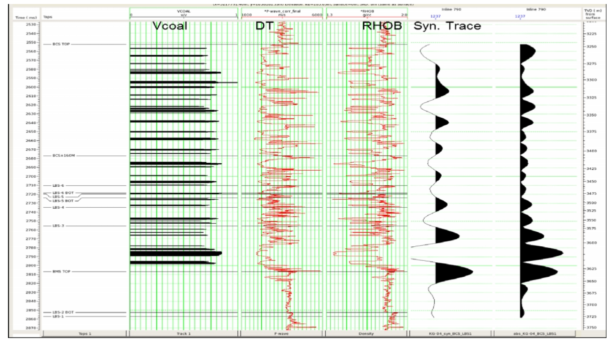

Fig.9: Absolute amplitude trace along with V_{coal} log for well A2 (~ 33 layers of Coal).

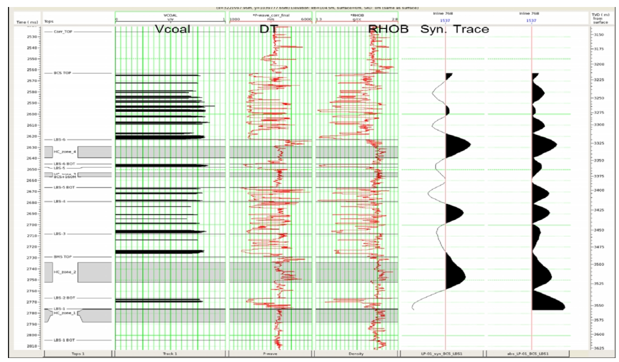

Fig.10: Absolute amplitude trace along with V_{coal} log for well C1 (~ 23 layers of Coal).

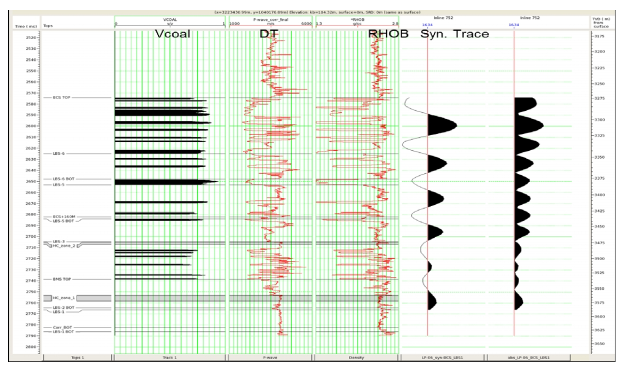

Fig.11: Absolute amplitude trace along with V_{coal} log for well C4 (~ 20 layers of Coal).

Analysis on Real Data

Attempt was made to validate above observations on real data. In real data between tops BCS to LBS1, though the coal proportion is nearly same for all the wells with exception of one or two wells, there is large variation in

AAA values spatially as shown in the fig.8. Three well locations (A2, C1& C4) were chosen in the above map to verify the modeling observations depending on number of coal layers distribution & disposition. As shown in AAA map, A2 is giving lower amplitude because of thinner, vertically uniform distribution of relatively more number of coal layers (fig.9). At well C1, AAA value is higher because of thicker, vertically non uniform distribution and relatively less number of coal layers (fig.10). Similarly, well C4 is falling in higher amplitude zone in AAA map, because of thicker, vertically non uniform distribution and relatively less number of coal layers (fig.11).

Pre-Stack Modeling

Pre-stack modeling was carried out to see the effect of coal on far offset amplitude. This modeling was done using elastic wave algorithm.

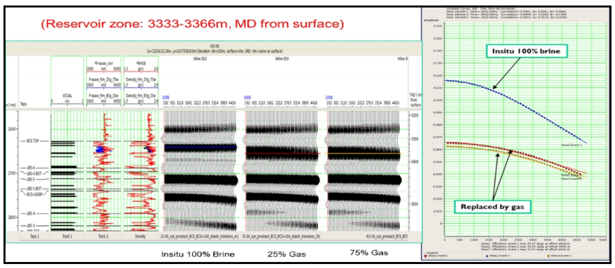

Fig.12: Prestack gathers generated using in-situ and FRM logs and AVO gradient analysis for well A4 (11% Coal).

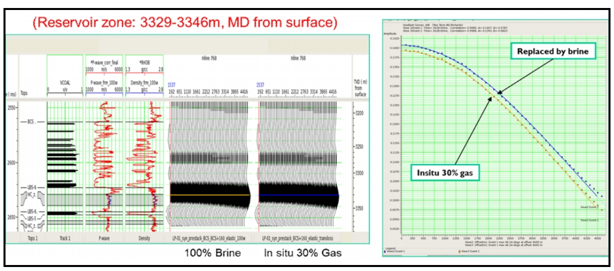

Fig.13: Prestack gathers generated using in-situ and FRM logs and AVO gradient analysis for well C1 (14% Coal).

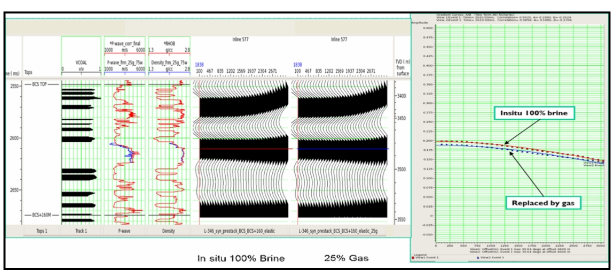

Fig.14: Prestack gathers generated using in-situ and FRM logs and AVO gradient analysis for well B4 (22% Coal).

To carry out this experiment, three wells, A4, C1 and B4 having coal proportion of 11%, 14% and 22% respectively, were considered. First, fluid replacement modelled (FRM) logs were generated for all three wells, to incorporate the effect of fluids. After that synthetic gathers were generated for both in-situ and FRM logs in each wells followed by AVO gradient analysis on these gathers to see the amplitude variation (fig.12-14). It shows that the amplitude gradient of synthetic gather for FRM logs is different in comparison to that for in situ logs in case of low coal percentage (fig. 12, well A4, 11% coal). On the other hand, the amplitude gradient of synthetic gathers for FRM logs is similar to that for in-situ logs if coal percentage is more (fig. 13 & 14).

Modeling Results

- Observations indicate that all three factors i.e. coal proportion, number of coal layers and relative disposition of thick and thin layers within the sequence contribute to seismic amplitude.
- The higher the near average absolute amplitude, the more likely it is to have higher coal content, while increasing far amplitude means a higher likelihood of oil/ gas occurrences.
- For the wells having lower percentage of coal, far offset amplitude is different for hydrocarbon and non-hydrocarbon bearing zones but when the percentage increases, no such difference is observed.
- Near and far offset amplitude maps used together may provide better prediction of hydrocarbon occurrences only when coal content is low.

Using these observations with reference to near stack and far stack amplitudes, an attempt was made to delineate the distribution of hydrocarbon sands within coal laminated sequence by deriving a fluid indicator attribute.

Combining NAAA & FAMP to Derive Fluid Indicator Attribute

Martin Kim et. al. (2003) showed the crossplot of near offset average absolute amplitude (NAAA) and far offset amplitude (FAMP) and diagrammatic representation of how the brine and oil/gas are expected to plot against each other, in presence of coal, in fig.15, based on the modeling, where m is the gradient of the brine cloud, and c is the intercept. Crossplot of NAAA and FAMP may indicate the most probable hydrocarbon zone corresponding to zone of lower value of NAAA and higher value of FAMP (mean of positive samples).

It would have been better to generate the maps and crossplot for individual coal and pay level, but it is not possible in present case as it is beyond seismic resolution.

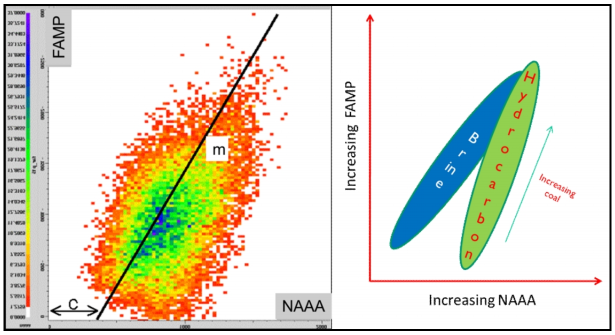

Fig.15: Crossplot of FAMP & AAA for deriving fluid indicator attribute (Source: Martin Kim et. al., 2003).

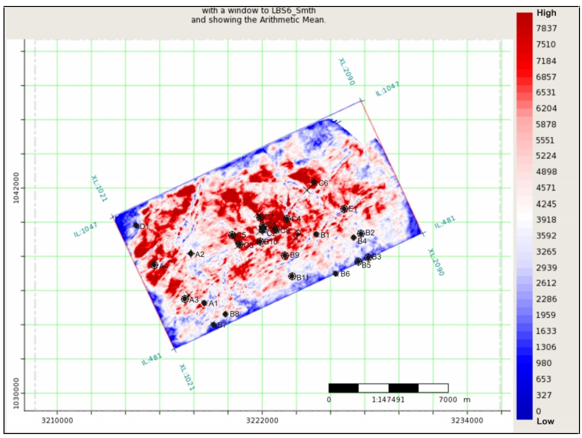

Fig.16: AAA from near offset stack for zone BCS-LBS6.

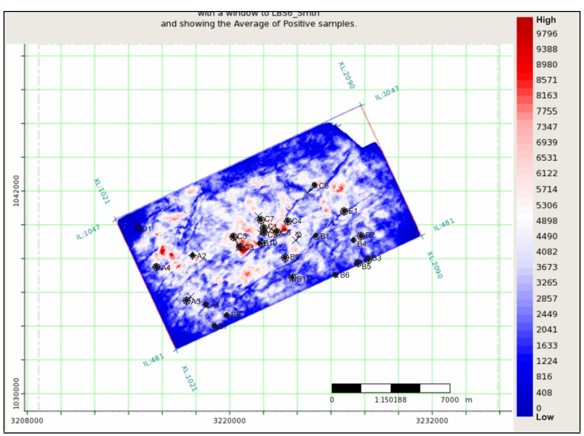

Fig.17: map of mean of positive samples of far stack for zone BCS-LBS6.

Analysis on Real Data:

PSTM gathers of the Laiplinggaon area was taken for analysis. Two stacks namely far and near offset stacks were generated from the PSTM gathers. For near stack range considered was 0-2000m and for far offset stack range was 2000-4500m.

Analysis window-1 (BCS-LBS6): Average absolute amplitude map was generated from near offset stack (NAAA) for zone BCS to LBS6 and shown in fig. 16. Map of mean of positive samples (pays correspond to peak) from far offset stack (FAMP) was generated for interval BCS-LBS6 and shown in fig. 17. Crossplot of NAAA and FAMP is shown in fig. 18. A trend line has been drawn on the crossplot with equation:

FarAmp (FAMP) =0.888163*NAAA-1147.82

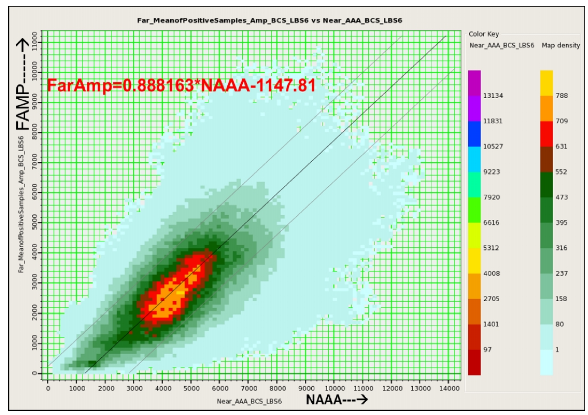

Fig.18: Crossplot of NAAA & FAMP for zone BCS-LBS6.

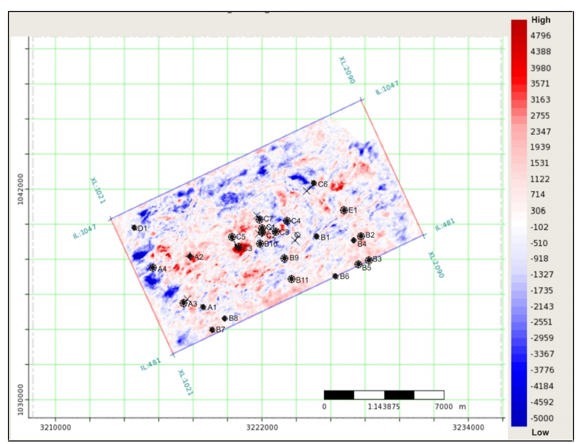

Fig.19: Fluid attribute map for the zone BCS-LBS6.

If background trend is removed, calculated from the crossplot of NAAA and FAMP (fig. 18) and a map is made after trend removal, it will represent the fluid attribute map. Fig. 19 shows the fluid attribute map for the BCS-LBS6. Positive values in the fluid attribute map indicate most probable hydrocarbon bearing locale in case of low coal content (<14%). No considerable area of interest is visible for this window in the fluid attribute map except at C3 well location which is very small in areal extent.

Analysis window-2 (LBS6-LBS1): Same process has been repeated for the window LBS6-LBS1. First the maps of NAAA and FAMP created for the window LBS6-LBS1, followed by crossplot between them. The crossplot between FAMP and NAAA for this window and background trend is shown in fig.20. The fluid attribute map generated after trend removal is shown in fig.21. Positive values in fluid attribute map (fig.23) indicate occurrence of probable hydrocarbon bearing zones for window LBS6-LBS1, which is validated by testing data in most of the wells having low coal content.

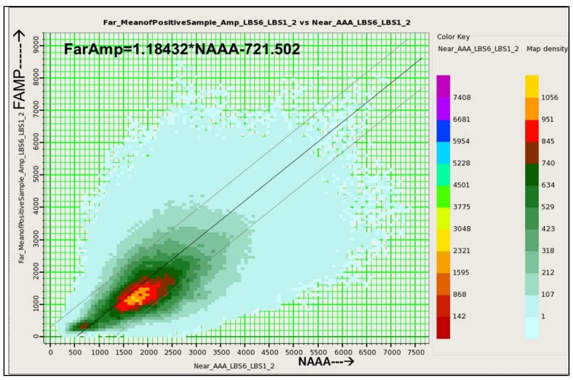

Fig.20: Crossplot of NAAA&FAMP for zone LBS6-LBS1.

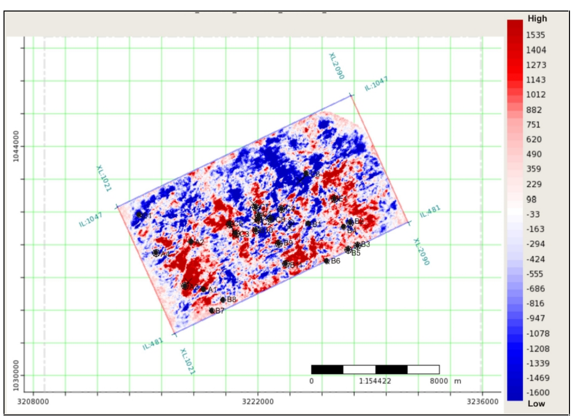

Fig.21: Fluid attribute map for the zone LBS6-LBS1.

Conclusions

- All three factors i.e. coal proportion, number of coal layers and relative disposition of thick and thin layers within the sequence contribute to seismic amplitude.
- AAA maps prepared for coal dominated sequence need to be interpreted with the above background information.
- The higher the NAAA, it is more likely of having coal content, while higher FAMP means higher likelihood of oil/gas, if coal percentage is less.
- Fluid indicator attribute after combining far and near amplitude for two different layers within BCS shows probable hydrocarbon bearing zones in low coal content regime which is validated in most of the wells.
- It would have been appropriate to generate the maps and crossplot for individual pay level, which is not possible in the present case as it is beyond seismic resolution.

References

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