Delineation of probable porous zones in carbonate build-up: A Case study from Andaman Basin, India

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Abstract

Delineation of subsurface reservoirs need detailed analysis of geophysical data. Inversion studies gives scope of de-risking the envisaged prospects in an identified area of work. Integration of seismic attributes with inversion results makes an interpreter more assured about the keen understanding of the subsurface. For any inversion, proper spatial distribution of wells is necessary to understand the nature of different litho-layers. Moreover, characterization of carbonate reservoir warrants much more focus on well data as reservoir properties laterally changes frequently. The current study area falls in the back-arc region of Andaman basin with good seismic coverage but no well has been drilled in the carbonate section. One well which has penetrated clastic section but has no favorable hydrocarbon shows is away from carbonate area. An innovative approach was adopted by drawing analogy from the far away well which had penetrated carbonate section in the same geological setup and carried out an inversion. Integration of inversion results with seismic attributes generated using AASPI consortium tool followed by unsupervised machine learning based facies classification helped in identification of porous zones in the carbonate build up.

Introduction:

Seismic data is the result of reflection from layer boundaries and depends upon the acoustic impedance contrast above and below the layer. It implies that seismic is an interface property and impedance is a layer property. Characterization of any reservoir depends on how close we analyze the layer property in terms of elastic in nature. Well data gives direct picture of the subsurface at a particular geographical location on the surface. Whereas seismic gives spatial subsurface coverage. Calibration of seismic to well data is the key step in an inversion to know about wavelet response. A good well coverage in the study area gives better confidence in reservoir characterization. The prime objective of the current study is to delineate porous zones in carbonate body of middle Miocene age. Major limitation is that no well was drilled in the envisaged carbonate section. Only one well, Well-A was available within the same 3D but was away from carbonate build up area which had penetrated only clastics.

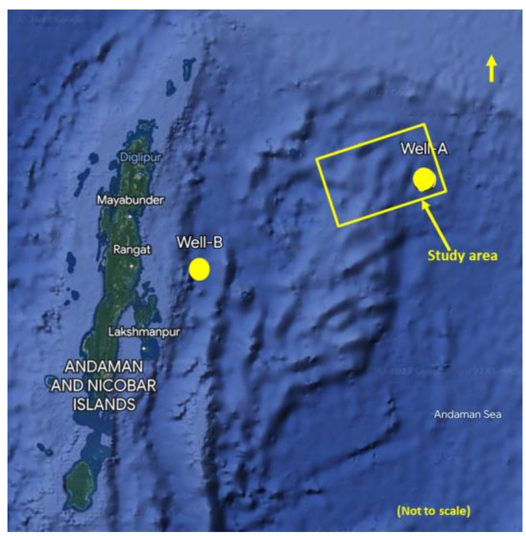

Figure-1 Geographical location of Andaman Basin and study area.

Figure-1 shows the Geographical location of Andaman Basin and study area which falls in the deep bathymetry of around 2000m. The Andaman-Nicobar basin, located in the southeastern part of the Bay of Bengal, occupies an area of 47,000 sq. km including deep waters. This basin forms a part of Island Arc System which extends from Myanmar in the north to Sumatra in the south with thick sedimentary sequence from Oligocene to recent (C Samajdar et al, 2013).

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Current study falls in the back arc region of Andaman & Nicobar Island area. Extensional back arc basins form where the angle of subduction of the down going slab is steep and the rate of subduction is greater than the rate of plate convergence. Rifting occurs in the region of the volcanic arc where the crust is hotter and weaker (At this stage an 'intra-arc basin' forms, a transient extensional basin that is bound on both sides by active volcanoes and is the site of accumulation of mainly volcanically derived sediment) (Figure-2).

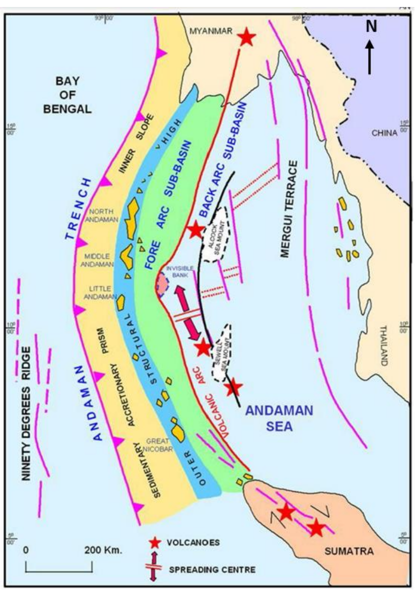

Figure-2: Tectonic map of the Andaman Basin

In the Andaman – Nicobar basin, the inner slope has not been probed by much of exploratory drilling so far. Many anticlinal structures within the Cretaceous-Oligocene sequence with fairly good source and reservoir facies form excellent entrapment conditions. Porosity pods within Tertiary limestones constitute excellent reservoirs in offshore Sumatra and in offshore Andaman. To the east of south Andamans, onlapping sedimentary sequences over the slope of magmatic arc provide ideal entrapment conditions for accumulation of sizeable hydrocarbons deposits. Porous facies in the carbonate section of Neogene are well developed in the northern part of Andaman Fore Arc basin. Southward extension of this element harbours large oil/gas fields in northern Sumatra (Arun gas field).

Current study area spreads in around 800 SKM which includes one well (Well-A). However, the study requirement was only 500 SKM which covered carbonate build-up with no well in the study area as shown in Figure-3. One well, Well-A is located in the current block, but not in the study area. Moreover, Well-A has penetrated the clastic section only. Hence analogy for impedance back ground trend for carbonate section, for low frequency model to be used in inversion, was drawn from the far away well, Well-B, (Refer Figure-1) and located nearly 225 km SW from Well-A, where a considerable thick (~600m) carbonate section was encountered.

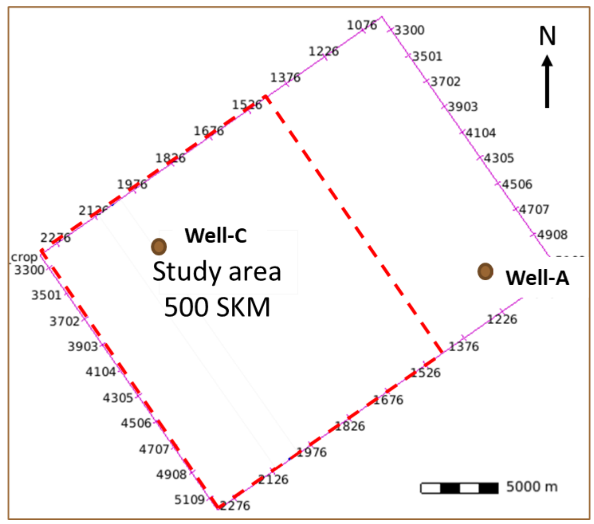

Figure-3. Base map showing study area with drilled wells. Red polygon showing study area for inversion.

Methodology Adopted:

The objectivity of the study was to characterize carbonate build up through post stack inversion to identify porous pods within the buildup. However, no well has penetrated this section in the area of interest. Following workflow was adopted to characterize the porous zones in carbonate body:

1. Seismic to well tie at Well-A
2. Model generation and inversion for clastic section. (For the entire area of 800 SKM).
3. Pseudo well (Well-C) creation at Carbonate build-up area (within Study area).
4. Trace extraction from inversion at pseudo well
5. Analogy from Well-B to understand the impedance trend of carbonate.

6. Applied High cut filter of 10 Hz for P-Impedance at Well-B
7. Incorporation of the same trend at Pseudo Well-C for carbonate section borrowed from Well-B
8. Iterative seismic to well (Well-C) tie until an optimum match between seismic and synthetic is achieved.
9. Model generation and inversion for carbonate section (Carbonate top horizon+500ms)
10. Inversion QC and attribute generation using AASPI tool
11. Unsupervised classification through machine learning method.
12. Integration of results.

Data QC:

The available seismic data has (Figure-4) full fold coverage and have high frequency. It has been observed that the high band width of the order of 5-90Hz @ -12db scale might be due to frequency enhancement on stack data. Increase in impedance is represented as peak at water bottom. As mentioned earlier, the current block has only one well, Well-A penetrated within Miocene section only. QC of all available curves in this well have been done. It was found that density curve hardly showed any depth trend although P-sonic was showing compaction trend. Carbonate top horizon was extended up to Well-A, to have spatial control over the study area while creating low frequency model although, Well-A had not penetrated carbonate body. Seismic to well tie was carried out for Miocene section iteratively and wavelet was estimated at well Well-A. Well tie has good correlation of the order of 70% (Figure-5). Structural framework was generated assuming all the surfaces were parallel to Miocene top as per geological understanding of the area. A P-Impedance model was generated in between Miocene top and extended Carbonate top horizon.

Inversion Phase-I

After model generation, post-stack inversion was done for Miocene section in whole study area. Figure-6 is showing the Inverted P-impedance section passing though Well-A for Miocene unit. P-impedance log, filtered in seismic bandwidth, overlaid on inverted section shows good match.

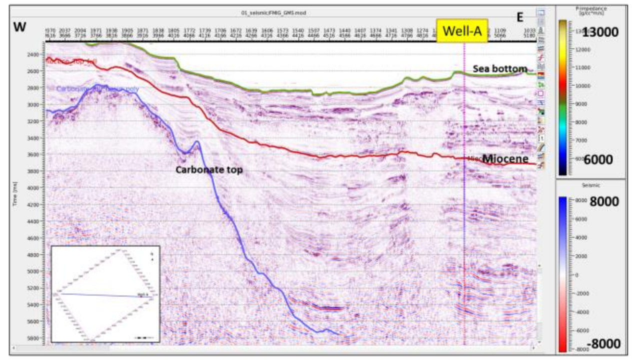

Figure-4: Seismic section passing through Carbonate area and Well-A showing data quality.

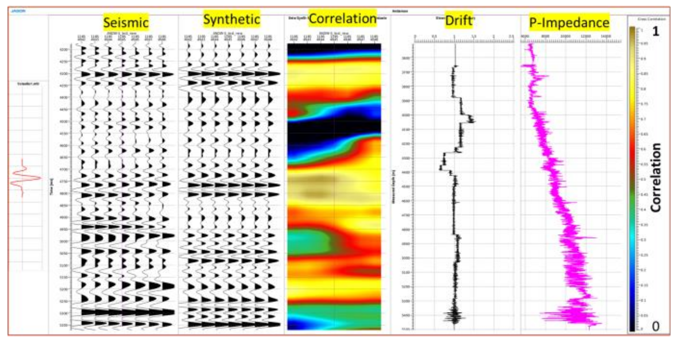

Figure-5: Seismic to well tie at Well-A showing good correlation in Miocene section.

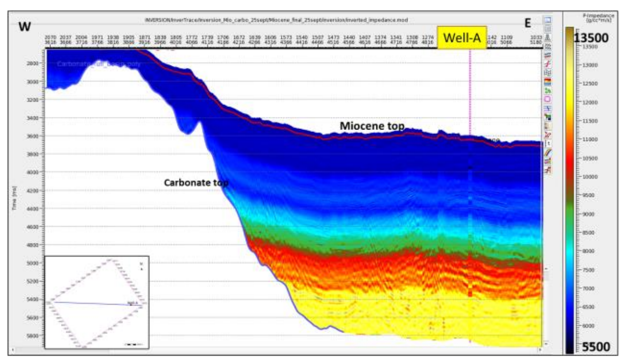

Figure-6: inverted P-impedance section passing through Well-A.

Inversion Phase-II

Once, the first phase of inversion was done, a pseudo well (Well-C) was created on the carbonate build up area. Impedance trace was extracted at Well-C from the phase-I inversion volume. Now a P-Impedance trace was available at pseudo well but only within Miocene section. Figure-7 shows seismic section passing through Well-B and the seismic character of carbonate in the section. Background trend of P-impedance for carbonate was assessed at Well-B and was borrowed for Well-C for carbonate unit. Available P-impedance log at Well-B show the impedance range for carbonate ranging from 8000-15000 m/s*g/cc as shown in Figure-8. A High cut filter of 10Hz was applied on P-Impedance curve of Well-B and was used as a back ground trend at pseudo well, Well-C for carbonate unit in the current study (Figure-8). Well to seismic calibration was done iteratively to match between seismic and synthetic for carbonate section (Figure-9).

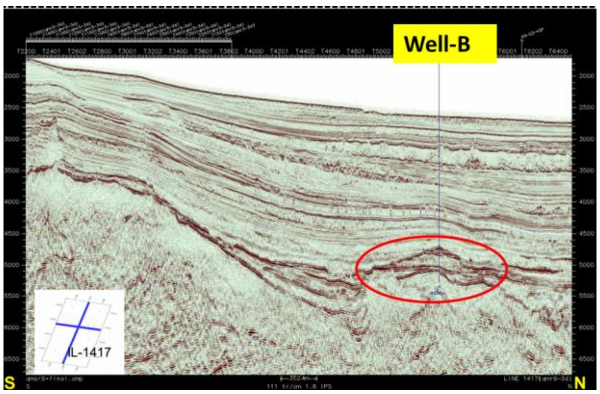

Figure-7: Seismic section passing through Well-B showing seismic character for carbonate section (red polygon).

A structural framework was generated assuming all surfaces are parallel to top and base and P-impedance model was generated from carbonate top to carbonate top + 500ms down. Parameter optimization followed by post-stack inversion were carried out.

An inverted in-line P-impedance section is showing relatively low impedance zones within carbonate section (Figure-10). Since, background trend for carbonate has been taken from well, Well-B and was iteratively improved, absolute values of P-impedance corresponding to carbonate will have uncertainty. It was suggested to interpret only relative variation of P-impedance values. A minimum P-Impedance was extracted within 100ms from the carbonate top to get variation of P-impedance within carbonate body.

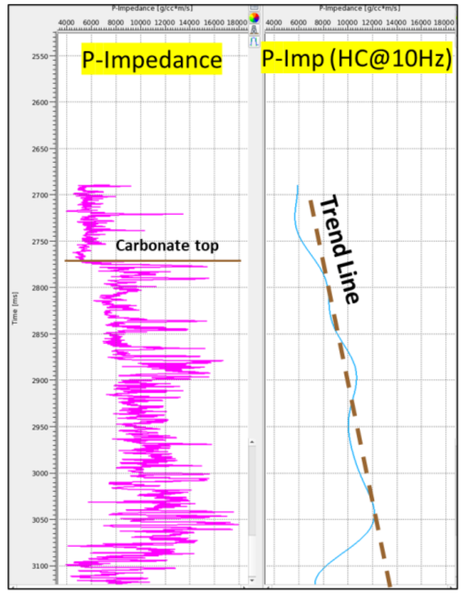

Figure-8: P-Impedance curve at Well-B and trendline at 10Hz high cut.

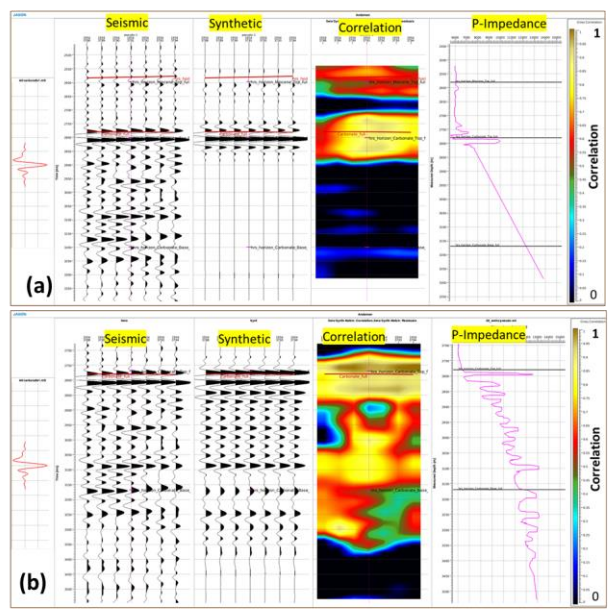

Figure-9: (a) showing poor well tie with simple trend line, (b) improved well tie after several iterations.

Some of the low impedance zones within carbonate are highlighted in the P-impedance slice as shown in Figure-11. Low impedance in carbonate body may be attributed to porous zones.

An attempt was made to classify inverted impedance along with some seismic attribute to reduce uncertainty due to low frequency background trend.

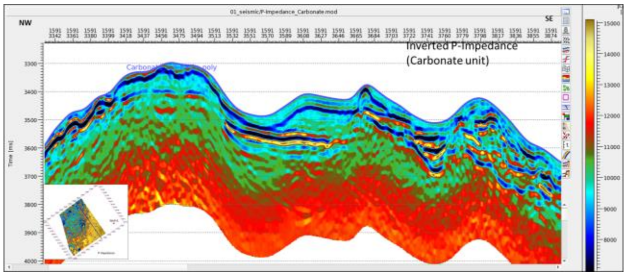

Figure-10: inverted impedance section for carbonate area.

Envelope seismic attribute was generated and used with inverted P-impedance during unsupervised clustering. The envelope is useful in highlighting discontinuities, changes in lithology, faults, deposition variation, tuning effect, and sequence boundary. The advantage of using this attribute instead of the original seismic trace values is that it is independent of the phase or polarity of the seismic data, both of which affect the apparent brightness of a reflection. Amplitude envelope will be high wherever there is a contrast due to changes in acoustic properties in the subsurface. Envelope slice close to carbonate top supports the impedance study where larger magnitudes correspond to lower impedances as shown in Figure-11.

Clustering

After inversion and attribute studies, it was decided to carry out unsupervised clustering (K-mean) using amplitude envelope, and inverted P-impedance. The inclusion of envelope in clustering will help to handle the uncertainty in P-impedance, due to uncertain background trend of Carbonate, up to some extent. The clustering was performed considering 4 classes.

Class-3 mainly represents the low P-impedance and high amplitude envelop and may be considered as porous zones within carbonate. Figure-12 shows the comparison of sections pertaining to Impedance from inversion, Envelope and classification through clustering portraying the anomalous zones (marked with ellipse) of low impedance, high envelop and class-3.

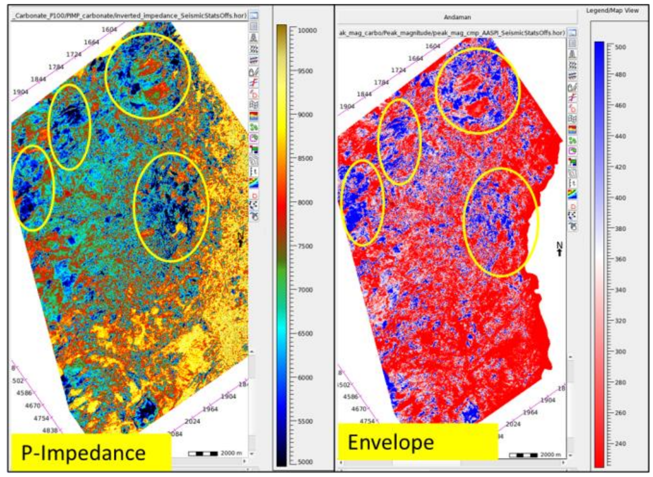

Figure-11: Horizon slices of Impedance and Envelope attribute showing high amplitudes zones with correspond to low impedance.

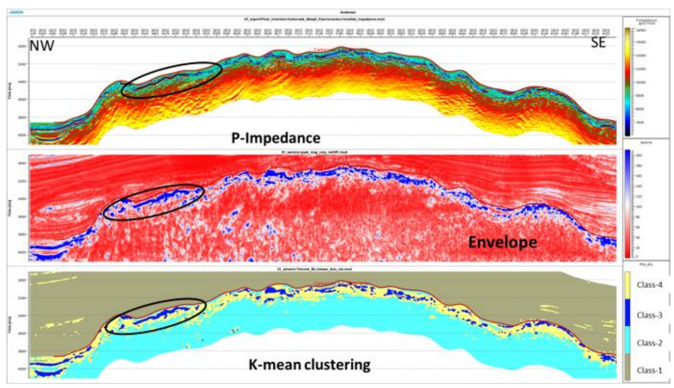

Figure-12: sections passing through inversion, envelop and unsupervised classification showing anomalous zones (black polygons).

Summary

Post stack inversion was carried out using the background trend of carbonate from Well-B. Some of the low impedance bodies were identified within carbonate body and may correspond to porous zones. Amplitude based attribute like amplitude envelop also support the low P-impedance bodies. To reduce the uncertainty of the background trend in inversion, P-Impedance along with envelop volume was used for un-supervised clustering to generate classified volume. Class-3 of classified volume corresponds to low P-impedance and high amplitude envelop and may be interpreted as porous zones within carbonate body.

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