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Deciphering the lateral extent of Basal Clastic sands by co-blending seismic attribute and well log data: A Case Study of Heera Field, Western Offshore Basin, India

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Abstract:

Considerable and sustained production rates from Basal Clastic Sand (BCS) unit of Panna formation of lower Eocene age of Heera field have drawn attention in recent past, despite the sand unit being interpreted to be thin and not of good quality. The proper integration of seismic attribute data and geostatistical analyses based on well log data is of prime importance to accurately predict the reservoir characteristics across the field. The Basal Clastics within the Panna formation are complex units both depositionally and lithologically. The depositional complexity ranges from sand – shale alteration with sands varying between conglomerates, fine grained to coarse grained with intervening occurrence of coal layers. The Basal Clastic top could only be interpreted at well logs and had no major seismic signature thus proving a challenge for the correlation.

Seismic amplitude and frequency based multitrace attributes were generated focussing on the Panna Formation between the Panna and Trap seismic horizons. Instantaneous and Dominant Frequency attributes were used and multiple filtering windows were used within the 0-32 Hz range using the horizon probe method in Petrel. Similar exercise was done with the RMS amplitude attribute for multiple windows within the 4500 – 12000 range and the two outputs were co-blended to give the geometry of a facies satisfying both the attribute conditions. The facies was then correlated with the GR and RHOB logs at various well positions with a high correlation coefficient establishing the Basal Clastic correlation across the field. The identified facies was mapped to establish the thickness of the Basal clastics which correlated well with the identified zones. There is a high degree of correlation between the RMS amplitude and Instantaneous frequency establishing the fact that the basal clastics are dominant by low frequency and high RMS amplitude.

Preparation of an accurate Geo-Cellular Model is predicated by the use of seismic inputs to establish the lateral reservoir facies dispersal. The present study establishes the BCT facies which could not be deciphered on the basis of a single seismic attribute could be better demarcated using the co-blending techniques using different frequency and amplitude window filters. This has opened up new areas of exploration within the Heera Field.

Introduction:

The exploration for hydrocarbons from Basal sands of Panna formation (Paleocene to Early Eocene) in the Mumbai offshore region, has always posed a challenge for exploration. The discrete occurrence of sand reservoirs vis-à-vis the lack of knowledge of their dispersal geometry limits the evaluation of prospective locales of these sands.

Proper mapping of the Basement and Panna formation tops are important pre-requisites for realistic assessment of exploitable hydrocarbons of Basal sands of Panna formation of Heera field. The Basal Clastics prove to be a challenge in identification on the seismic sections and thus using the well markers in time as input stratal slices were composed to account for the basal clastic interpretation in time. The identification of the Basal Clastics and in particular the areas of good reservoir facies therein was determined by a co-blending of frequency and amplitude based attributes at various windows to get the best image of the lateral dispersion geometry.

Geology of the area

Mumbai offshore is a pericratonic rift basin situated on western continental margin of India. Towards NNE it continues into the onland Cambay basin. It is bounded in the northwest by Saurashtra peninsula, north by Diu Arch. Its southern limit is marked by east west trending Vengurla Arch to the South of Ratnagiri and to the east by Indian craton. Five distinct structural provinces with different tectonic and stratigraphic events can be identified within the basin viz. Surat Depression (Tapti-Daman Block) in the north, Panna-Bassein-Heera Block in the east central part, Ratnagiri in the southern part, Mumbai High-/Platform-Deep Continental Shelf (DCS) in the mid-western side and Shelf Margin adjoining DCS and the Ratnagiri Shelf (Fig. 1).

Panna-Bassein-Heera block is located south-east of Mumbai High/Platform and south of Surat Depression has three distinct N-S to NW-SE trending tectonic units which lose their identity in Miocene. The western block is a composite high block dissected by a number of small grabens. The Central graben is a syn sedimentary sink during Paleogene and Early Neogene. The eastern block is a gentle eastward rising homocline. Hydrocarbons occur at multiple levels in through a number of platforms.

The Panna formation unconformably overlies the basement. It is overlain unconformably by Bassein formation of Lower to Middle Eocene age except in and around crestal part of Heera structure where it directly comes in contact with Mukta formation of Lower Oligocene age. Panna formation heralds the first marine incursion into the area. The general lithology of the formation consists of predominantly basement/ trap derived conglomerate with clay and sand matrix in the lower part followed by clay stone, shale and siltstone in the upper part. The top of the Panna formation is an erosional unconformity. Hitherto, the actual wedge out limit of other younger producing formations (viz. Bassein and Mukta formations) and their respective thickness are not exactly known in the crestally shallower part of the Heera structure due to the absence of proper mapping of Panna and Basement formation tops which lie just underneath. Besides, Panna formation also shows considerable thinning in the crestal part of Heera field (Fig. 1)

The field is in mature stage of development and has about 200 wells, which are producing from different reservoirs. Except a few exploratory and vertical development wells, most of the wells are directional development wells from production and injection platforms. Around 54 wells from Basal clastics have cumulatively produced 4.384 MMT oil.

Methodology:

A seismic attribute is a measurement derived from seismic data and is commonly based on measurements of time, amplitude, frequency, and/or attenuation and is a powerful aid to interpreters. By enhancing the interpreter's ability to recognize useful geologic patterns from seismic data, seismic attributes can be a proper carrier of seismic information for geologic interpretation. However, seismic attributes are limited by seismic resolution, and uncertainties can arise in interpretation. In addition to errors related to algorithms and noise, two primary sources of uncertainty are non-uniqueness of seismic surface picking and of seismic facies definition. This study is an attempt to demonstrate that both these issues are related to frequency dependency of seismic attributes. Seismic data of different frequency bands may address seismic events and seismic facies of different geologic scales. Analysis of frequency driven seismic-interference patterns may significantly reduce uncertainty in seismic interpretation, especially in seismically thin depositional sequences. In this study, although only the stratigraphic interpretation of basic amplitude and instantaneous attributes is discussed, similar procedures and conclusions should be applicable to other seismic attributes (e.g., geometric attributes such as curvature, coherence, and others). Understanding frequency-dependent seismic interference is a key to reducing uncertainties in the stratigraphic and facies interpretation.

- **Establishment of BCT interpretation:** The Basal Clastics zone under investigation here in this study lies between the Panna top and the Basement top (the formation is carbonate dominated) and was not marked by a good seismic reflector. Thus on the basis of geological interpretation from the well logs, the markers were transferred to time domain with appropriate Time Depth relationship and a conformable surface was created in the time domain by using the basement and Panna level interpretations with the well marker interpretations. (Fig. 2).

- **Seismic Attribute Generation:** Dominant and instantaneous frequency attributes were generated for the seismic volume to get an estimate of the reservoir facies thickness. Frequency dependence offers a new dimension of seismic data, which has not been fully used in seismic interpretation of geology. A stratigraphic formation is typically composed of lithofacies of varying thicknesses, and a broadband, stacked seismic data set is not necessarily optimal for stratigraphic and facies interpretation. Although it is difficult to predict correct frequency components for interpretation of not-yet-known geologic targets, local geologic models and well data can be used to optimize the frequency components of seismic data to a certain degree and intentionally modify seismic-interference patterns and seismic facies for better seismic interpretation of geologic surfaces, sediment-dispersal patterns, geomorphology, and sequence stratigraphy. Root Mean Square (RMS) Amplitude was generated for the seismic volume which has been proven to provide indication of hydrocarbon bearing facies. The instantaneous frequency was filtered in opacity with ranges between 0-32 Hz to get the requisite thickness of the reservoir facies. The RMS amplitude was used in the range of 4500 – 12000 to determine the quality of the facies. The frequency of the seismic volume under study is established and is found to be dominantly in the range of 11-32Hz. (Fig. 3).

- **Correlation with Well Logs:** The RMS amplitude was matched at the existing well locations to get a good correlation with the reservoir facies. A cross relationship between extracted RMS amplitude and Instantaneous frequency versus gamma ray log at different well locations was carried out. RMS amplitude is found to be inversely proportional to Inst. Frequency. The Inst. frequency of the entire seismic volume is generated which is found to be directly proportional to GR whereas the RMS amplitude is found to be inversely proportional to GR (Fig. 4) thus establishing a high correlation coefficient at various well positions for the Basal Clastic around the field. This relationship was used and the two were co-blended to give the geometry of a facies satisfying both the attribute conditions. The identified seismic facies was also posted in the well correlation for the wells at various locations to establish the thickness of the facies with the identified log correlated zones (Fig. 5).

- **Attribute Co-Blending:** Using the Horizon Probe mode in Petrel, the seismic volume was extracted exclusively in the Basal Clastic Zone and the instantaneous frequency and RMS amplitude attributes were co-blended in the zone with appropriate filters for both, to provide an estimate of the lateral extent of the reservoir facies. Preparation of an accurate Geo-Cellular Model is predicated by the use of seismic inputs to establish the lateral reservoir facies dispersal. The frequency and the RMS amplitude in the established range are co-blended (Fig. 6) which has demarcated areas with good reservoir facies having appropriate thickness for producing hydrocarbons.

Results:

- Amplitude and Frequency attributes were plotted against each other after the requisite filters were applied giving a negative correlation of 75% establishing high RMS amplitudes at regions of low frequency as good quality reservoir facies.
- The co-blended seismic volume was correlated with the well locations using crossplots establishing that the requisite thickness and quality of the facies as established by the GR and RHOB, used as lithology discriminator logs, were matching with the co-blended seismic attributes.
- The map of the co-blended attribute overlain with the structural maps and the production history of the already drilled wells establishes the validity of the result. (Fig. 6)

Blending both of these together helped us demarcate the regions of good quality reservoir facies while applying a thickness cutoff eliminating the extremely thin reservoirs. This was then correlated at various well locations with the GR and RHOB logs to determine facies thickness and quality and the correlation coefficient was calculated between the seismic attributes and the well logs thus effectively incorporating both the data to arrive at a stronger conclusion.

Conclusions:

The present study establishes the BCT facies which could not be deciphered with confidence and certainty on the basis of a single seismic attribute could be better demarcated using the co-blending techniques using different frequency and amplitude window filters. It also opens up areas to the north-and the south encircled in red and blue respectively which could be explored as there are few existing wells and which show promise in terms of structure, facies as well as production from nearby wells (Fig. 6) . The result can be made used as a secondary input for the preparation of Geo-Cellular model (GCM) to establish the lateral reservoir facies dispersal.

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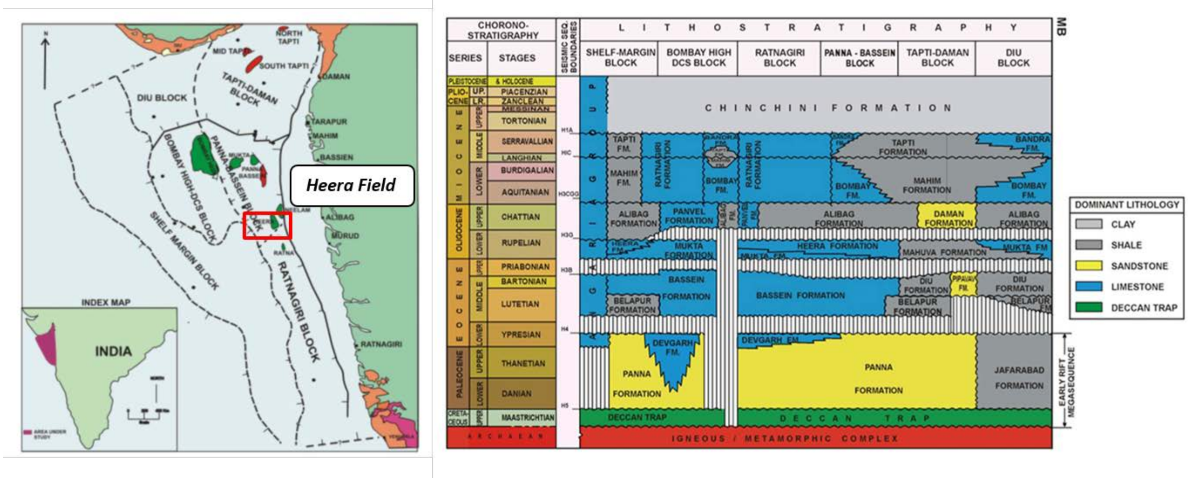

Fig 1. Map of Heera Field and General Stratigraphy of the region

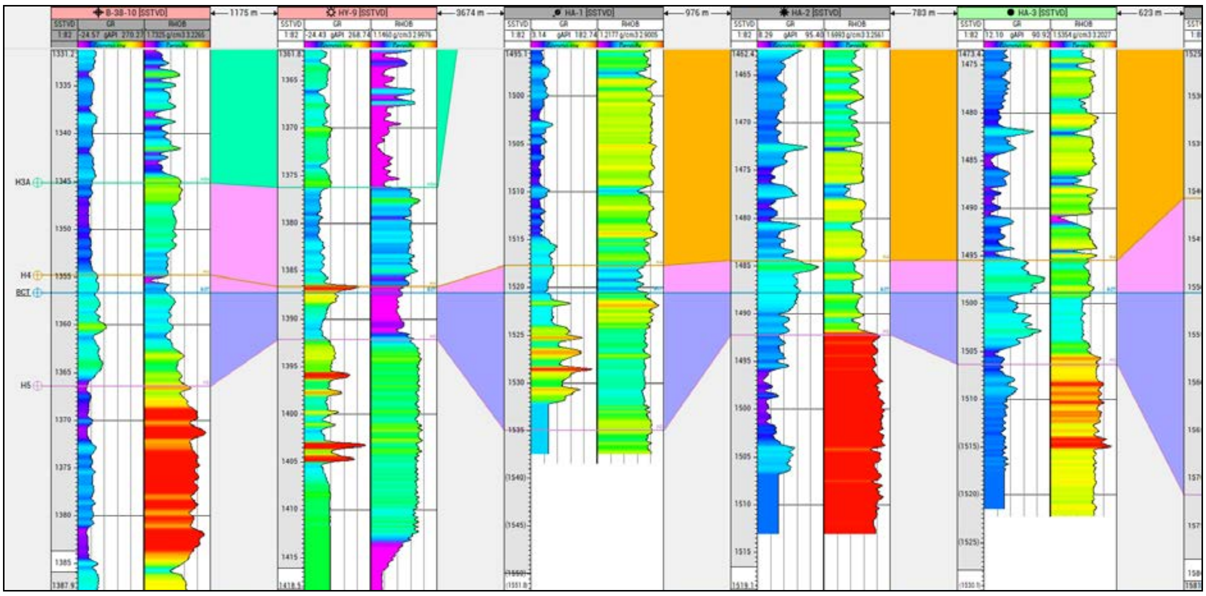

Fig 2. Electrolog Correlation of Basal Clastic Top formation across the wells showing characteristic GR and RHOB signature.

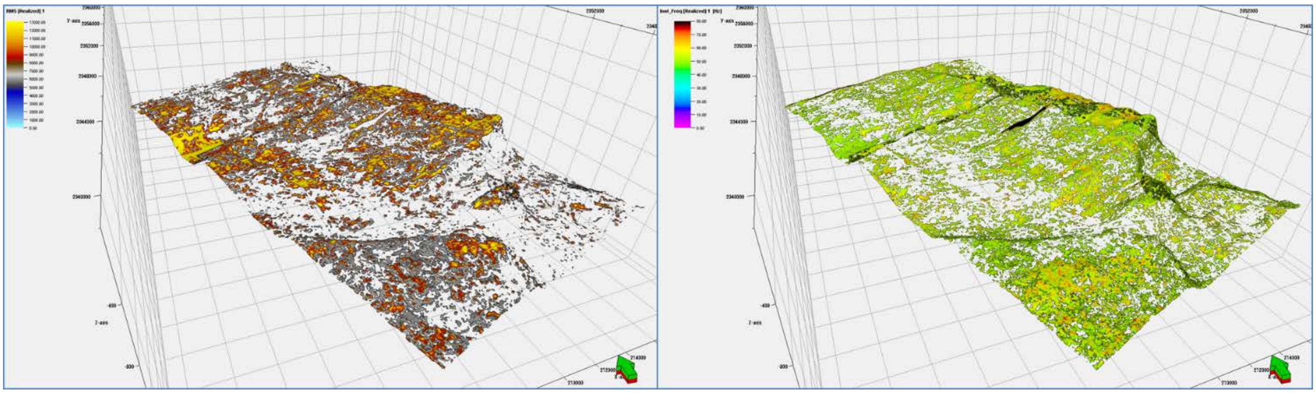

Fig3. RMS Amplitude (4500-12000) and Instantaneous Frequency (11-32Hz) attributes extracted in the Basal Clastic Zone in 3D horizon Probe method

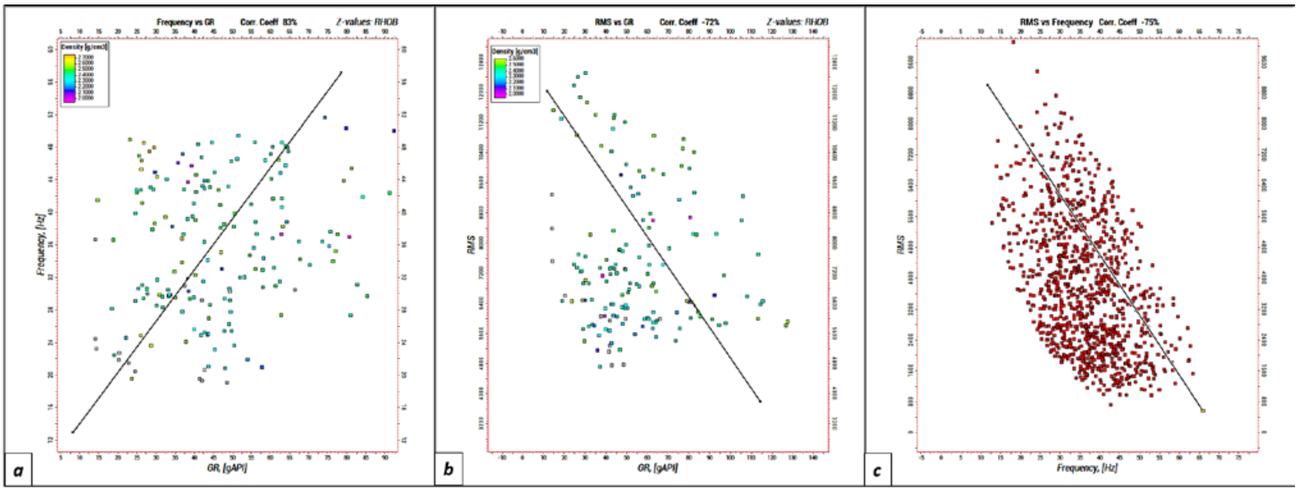

Fig 4. Crossplots correlating log and seismic attributes a) Frequency vs. GR (corr. coeff. 63%) b) RMS vs GR (corr. coeff. -72%) c) RMS vs Frequency (corr. coeff. -75%)

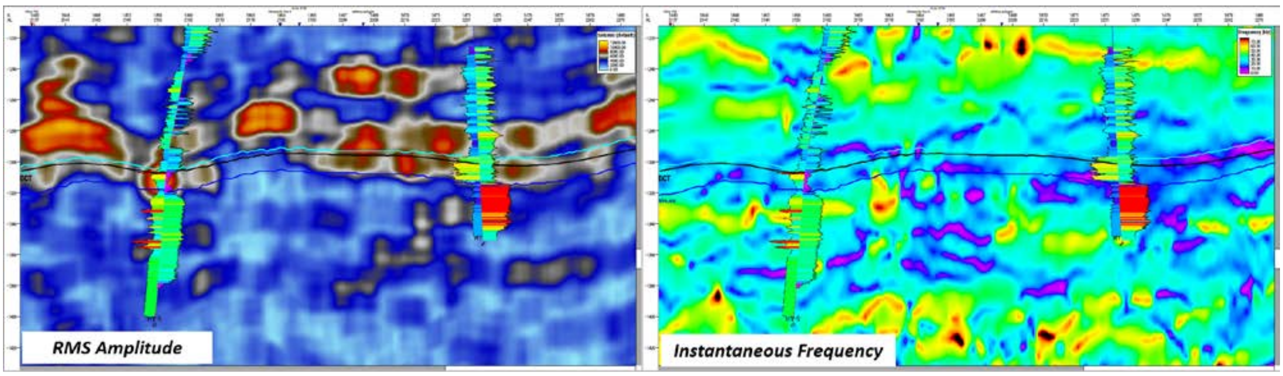

Fig 5. Section showing correlation between RMS Amplitude and Instantaneous Frequency with GR and RHOB logs in BCT Zone

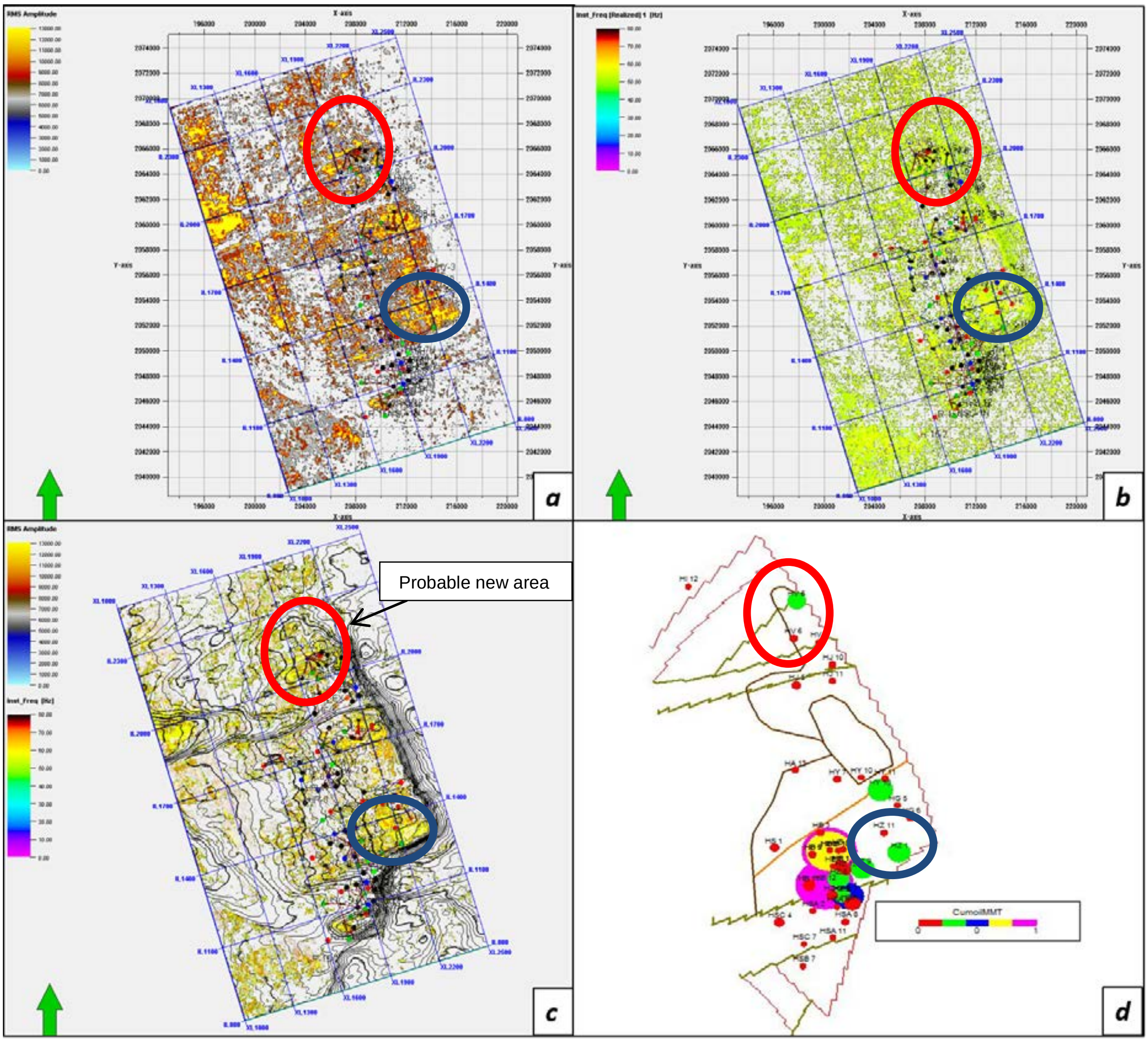

Fig 6. a) 4500- 12000 range filtered RMS Amplitude in the Basal Clastic Zone b) 11-32Hz filtered Instantaneous Frequency in the Basal Clastic Zone c) Co-Blended attribute with overlying structural contours d) Bubble plot of wells producing from the Basal Clastic zone