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Amplitude Frequency Discriminator as an Effective Attribute in Dim Spots of Rohtas Formation, Son Valley, Vindhyan Basin, India

Keywords

Attribute, Amplitude Envelop and Instantaneous Frequency, AFD, Dim Spot

Abstract

Seismic attributes are very popular tool in E&P industry to extract hidden information from seismic data regarding faults, structure, depositional environments, direct hydrocarbon indicator etc. A new instant attribute called Amplitude Frequency Discriminator (AFD) is formulated from Instantaneous frequency and Amplitude envelope attributes for identifying hydrocarbon bearing dim spots in sedimentary formation. And effectiveness of the AFD attribute is tested to identify dim spot in Rohtas Formation of Son Valley, Vindhyan basin, India. The AFD attribute shows consistent result for three discovered gas wells in the Son Valley area. As observed low to moderate magnitude of AFD attribute is the main characteristic for the gas zones in different wells. A comparison study between Sweetness attribute and AFD is also carried out and it is found that newly formulated AFD attribute is more effective to identify dim spots (hydrocarbon bearing zones) of Rohtas Formation.

Introduction

Vindhyan basin is a Proterozoic Basin in central part of India, situated between the Delhi - Aravalli orogenic belt to the NorthWest and Son-Narmada Geo-fracture to the South. The Bundelkhand Massif, located in the NorthEast part of the basin, divides it into two sectors: Son Valley to the East and Chambal Valley to the West (Figure 1). The basin fill in Son Valley constitutes a considerable thickness (2- 6 Kms.) of unmetamorphosed, varyingly deformed sedimentary succession. Carbonate dominated Lower Vindhyan (Semri Group) and clastic dominated Upper Vindhyan (Kaimur, Rewa and Bhander Groups) sequences of this basin are separated by a large unconformity. In the Lower Vindhyan succession of Rohtas Limestone Formation, gas presence has already been established. On the basis of lithological characteristics and well log results, Rohtas Formation can be broadly classified into three litho-units i.e. Upper Rohtas, Middle Rohtas and Lower Rohtas units. The Lower Rohtas (LR) unit consists of argillaceous limestone with interbed of cherty / silty shale. The Middle Rohtas (MR) unit is dominantly argillaceous in nature represented by alternations of argillaceous limestone and calcareous shale. The Upper Rohtas (UR) unit is dominantly argillaceous limestone with thin laminations of shale. All these sediments are of the earliest origin i.e. Proterozoic period accordingly very tight in compaction resulting

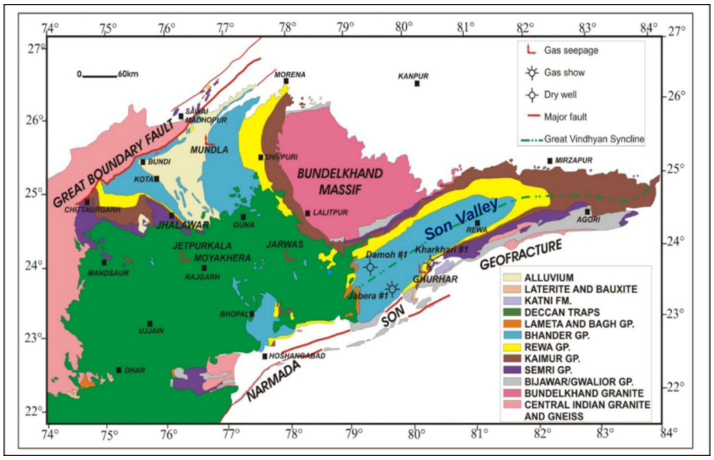

Figure 1: Geological Map of Vindhyan Basin

into high seismic velocity (~ 5000 ± 500 m/s) in-turn high impedance and low primary porosity and low permeability. However fault framework has helped in the development of secondary porosity facilitating creation of sweet spots. As Vindhyan sediments are typically characterized by high impedance regime, so preponderance of dim spots is in abundance. Present study is focused on dim spots and their manifestation by applying seismic attribute called Amplitude Frequency Discriminator (AFD).

Background

Seismic attributes are the constituents of the seismic data and these are attained by different mathematical methods, computation and measurement from the seismic data. Seismic attributes extract hidden information regarding faults, structure, depositional environments, and hydrocarbon habitat for prospectivity analysis. These attributes are sometimes used as direct hydrocarbon indicator like bright spot, dim spot and flat spot identification. Attributes are representation of seismic data from the concept of complex trace of seismic data which are represented by constituents like real part and imaginary part.

( )= ( )+ ( ) …………… (1)

Where *c(t)* : complex trace; *f(t)* : seismic trace; *h(t)* : Hilbert transform of the real trace. Complex trace can be represented in terms of envelope *A(t)* and the instantaneous phase *φ(t)*;

( )= ( ) ^(( )) ..………… (2)

Where ( )=√((( ))^ +(( ))^) and ( )= (( )/ ( )).

Here real part is the seismic trace and imaginary part is the Hilbert transform of the seismic trace. Applying mathematical application, one can compute instantaneous attributes like amplitude envelope and instantaneous phase etc.

Now by definition Instantaneous frequency is the time derivative of the instantaneous phase (Taner et al., 1979).

( )= ^′ ( )= [(^′ ( ))/(( ))] ………… (3)

In terms of the input seismic trace and its Hilbert transform, the instantaneous frequency can be defined as;

( )= (( ) ^′ ( )− ^′ ( ) ( ))/[(^ ( ) | ^ ( ))] ………………. (4)

Using this amplitude envelope and instantaneous frequency sweetness attribute is generated which is a popular attribute for bright spot identification of relatively younger sediments containing hydrocarbon reservoirs.

Sweetness $S = A(t)/f(t)$ ……………………… (5)

Hydrocarbon saturated sands in younger sediments show high magnitude of Sweetness (S) because presence of hydrocarbon lowers the impedance of the reservoir in-turn increases impedance contrast which enhances the amplitude envelope and lowers the frequency (Hart 2008). It is difficult to identify a dim spot in a seismic section and it is found when a high impedance reservoir is encased within relatively lower impedance layers. So, In case of dim spot opposite phenomenon is observed where presence of hydrocarbon lowers impedance decreasing impedance contrast in-turn diminishing amplitude envelope with lowering of instantaneous frequency.

Methodology

In the instant attribute study of Rohtas Formation of Vindhyan Basin, dim spot hydrocarbon reservoirs are dealt with analysis of Sweetness (S) and Amplitude Frequency Discriminator (AFD) attributes and their efficacy in bringing out sweet spots in limestone sediments.

Amplitude Frequency Discriminator (AFD):

A new attribute called Amplitude Frequency Discriminator (AFD) is calculated in combination of amplitude envelope and instantaneous frequency to identify the dim spot of Rohtas Formation. It is defined as amplitude envelope *A(t)* multiplied by the square root of the instantaneous frequency *f(t)*.

Amplitude Frequency Discriminator (AFD) AFD ( ) **=** $At*(absft$ ……………. (6)

Presence of hydrocarbon in high impedance sediments reduces the contrast in acoustic impedance (between high impedance reservoir and relatively lower impedance background) diminishing amplitude envelope with reduced instantaneous frequency. Multiplication of reduced amplitude envelope and square root of reduced instantaneous frequency generates lower magnitude compared to background resulting into improved manifestation of dim spot in-turn hydrocarbon sweet spot.

The AFD attribute was computed in Hampson-Russell software (HRS). First, a seismic and well database was created and necessary data were uploaded in Hampson-Russell software (HRS). Amplitude envelope and instantaneous frequency volumes were generated by taking 3D seismic data as input. This operation was performed using ‘Single trace Seismic Attributes’ module of HRS software. Then ‘Trace Maths’ module was invoked to compute the AFD attribute for which amplitude envelope and instantaneous frequency as described above were used as inputs. In ‘Trace Maths’ module multiplication of the two input volumes i.e., amplitude envelope and square root of instantaneous frequency was performed to get AFD attribute (Figure 2). The output volumes of Amplitude Envelope, Instantaneous Frequency, AFD and Sweetness attribute were generated for Rohtas Formation.

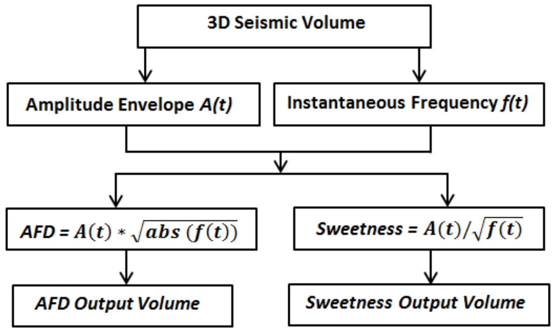

Figure 2: Flowchart for computation of AFD attribute and Sweetness attribute.

Output volumes of the AFD attribute and Sweetness attribute are analyzed in different gas zones of three wells of Nohta area. In this paper results of these attributes are analyzed and presented below.

Results

Results for well Nohta#A:

Figure 3a shows the input seismic data and figure 3b and figure 3c describe corresponding amplitude envelope and instantaneous frequency respectively. For Upper Rohtas unit (UR unit, *Lithology : Shale and Limestone*) clear Dim Spots are observed with low magnitude of AFD attribute. Presence of gas drastically reduces the magnitude of AFD (Figure 3d).

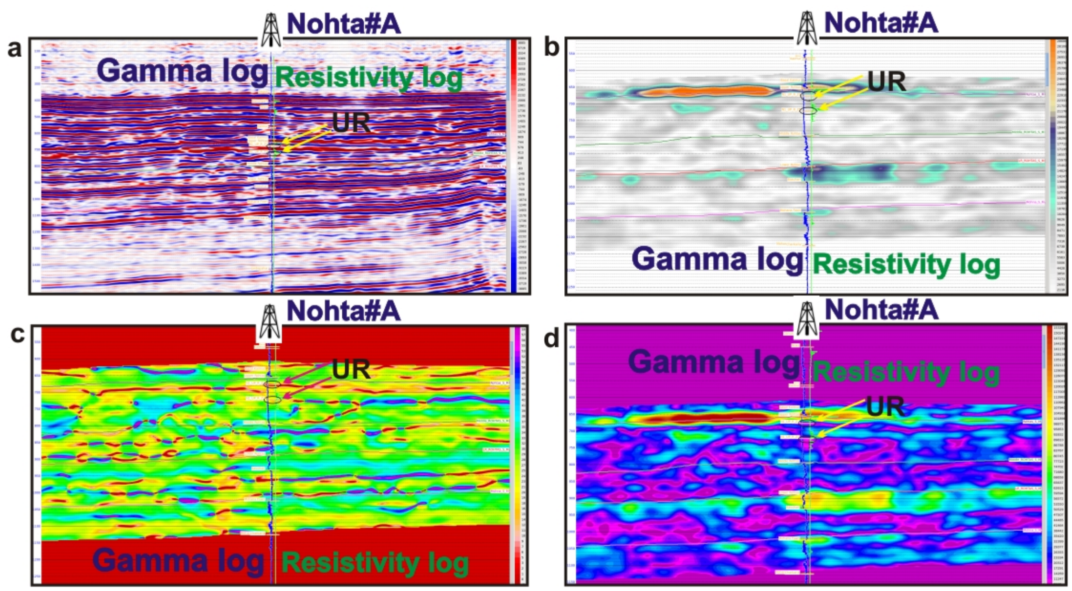

Figure 3: a) Input seismic data for Amplitude Envelope and Instantaneous Frequency calculation for well Nohta#A b) Amplitude Envelope; c) Instantaneous Frequency d) AFD attribute (black ellipses in all figures describe the gas zones of Upper Rohtas unit (UR)).

Results for well Nohta#C:

Figure 4a shows the input seismic data and figure 4b and figure 4c describe corresponding amplitude envelope and instantaneous frequency respectively. In case of Upper Rohtas unit (UR) and Middle Rohtas unit (MR), Dim Spots are clearly visible in the gas zones but in Lower Rohtas unit (LR), AFD attribute showing comparatively higher value because of higher depth (Figure 4d). In these different zones, presence of gas drastically reduces the magnitude of AFD (Figure 4d).

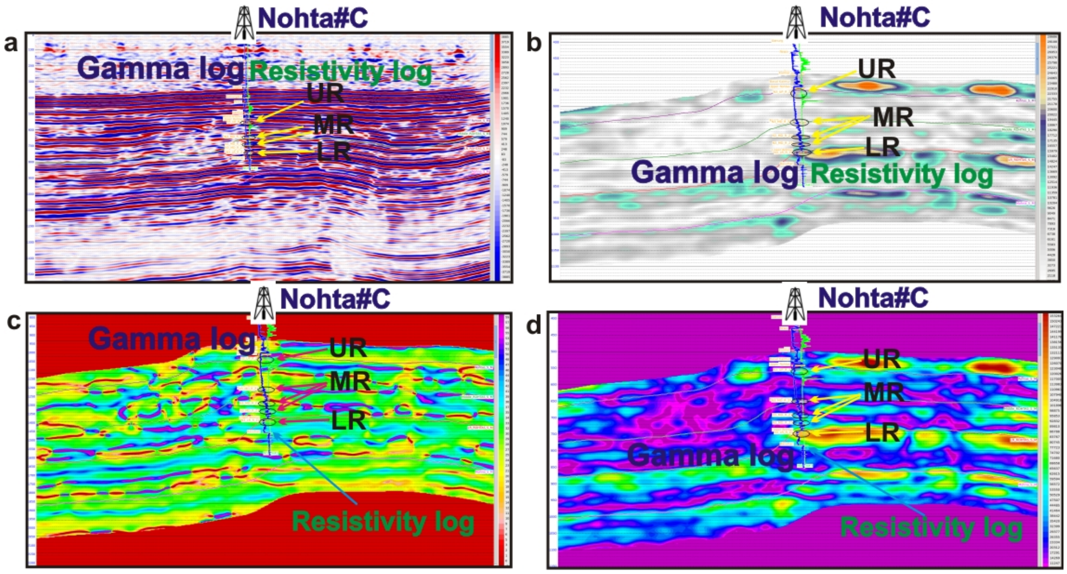

Figure 4: a) Input seismic data for Amplitude Envelope and Instantaneous Frequency calculation for well Nohta#C b) Amplitude Envelope; c) Instantaneous Frequency d) AFD attribute (black ellipses in all figures describe the corresponding gas zones of Upper Rohtas unit (UR), Middle Rohtas unit (MR) and Lower Rohtas unit (LR)).

Results for well Nohta#F:

Figure 5a shows the input seismic data and figure 5b and figure 5c describe corresponding amplitude envelope and instantaneous frequency respectively. In case of Upper Rohtas unit (UR) and Middle Rohtas unit (MR), Dim Spots are clearly visible in the gas zones but in Lower Rohtas (LR), AFD attribute showing comparatively higher value because of higher depth (Figure 5d). In these different zones, presence of gas drastically reduces the magnitude of AFD (Figure 5d).

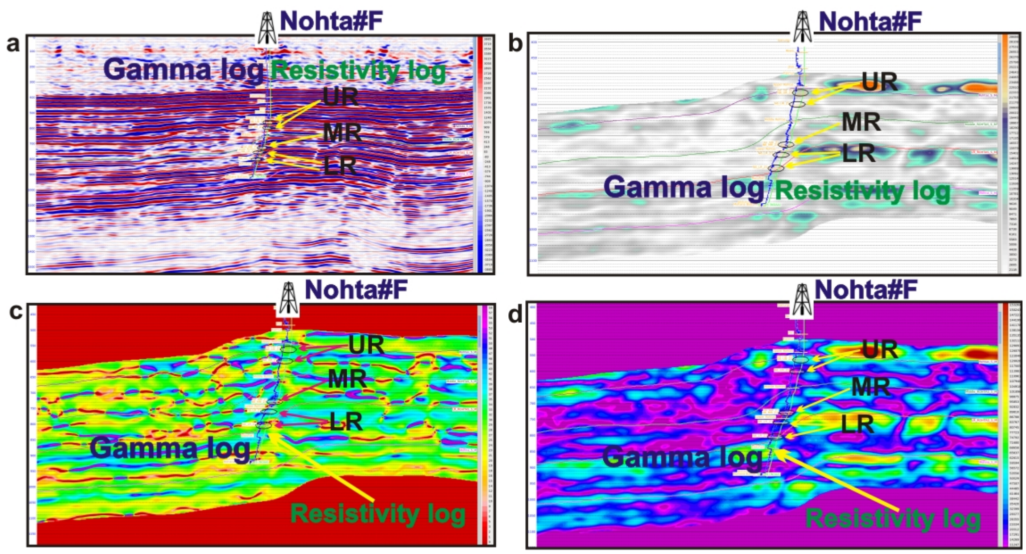

Figure 5: a) Input seismic data for Amplitude Envelope and Instantaneous Frequency calculation for well Nohta#F b) Amplitude Envelope; c) Instantaneous Frequency d) AFD attribute (black ellipses in all figures describe the corresponding gas zones of Upper Rohtas unit (UR), Middle Rohtas unit (MR) and Lower Rohtas unit (LR)).

Discussion

Results of AFD attribute from the above discussed three wells illustrate the effectiveness of this attribute for identifying the Dim spot in different units of Rohtas Formation where attribute magnitude becomes very low. For well Nohta#A gas show indicates only in the Upper Rohtas unit. For wells Nohta#C and Nohta#F gas shows are present in all three units of Rohtas Formation (Upper unit, Middle unit and Lower unit). Amplitude Envelope value is low and Instantaneous Frequency value varies from low to moderate for two gas zones in upper Rohtas formation in Nohta#A well. As a result AFD magnitude becomes low for those particular gas zones. In case of well Nohta#C for Upper and Middle Rohtas units, low Amplitude Envelope and low to moderate Instantaneous Frequency values are present but for the Lower Rohtas unit, Amplitude Envelope value is comparatively higher and Instantaneous Frequency value is moderate. Presences of Cherty Shale and overburden in the Lower Rohtas unit increase the impedance difference and as a result amplitude value becomes comparatively higher than that of Upper Rohtas unit and Middle Rohtas unit. Low to moderate Instantaneous Frequency values and low Amplitude Envelope values are found in all three units of Rohtas Formation in the well Nohta#F. We have also computed the Sweetness Attribute volume and compared the results with AFD volume (Figure 6). AFD attribute shows consistent results as compared to Sweetness Attribute. From figure 6, it is clear that for the same Upper Rohtas unit in two gas bearing zones Sweetness Attribute is showing different magnitude (one is very high (red colour) and another one is low (blue colour)) but AFD attribute is showing persistent result for the same gas bearing zones of very low magnitude (purple colour). Ratio of magnitude of AFD attribute to magnitude of background (~ 15) for gas bearing zones was calculated. The same ratio was calculated for Sweetness Attribute (~ 6) as well for comparison between the two ratios. The results show that the ratio of AFD attribute is relatively higher than that of ratio of sweetness attribute providing wider range of dim spot discrmination.

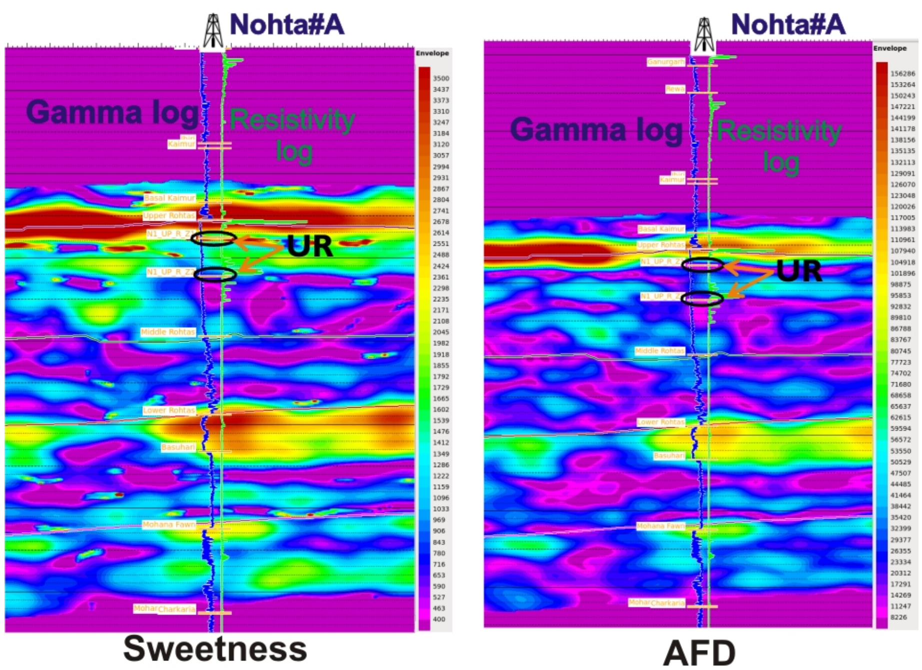

Figure 6: Results of Sweetness and AFD attributes for Well#A.

Conclusion

A new instantaneous attribute named Amplitude Frequency Discriminator (AFD) is formulated and successfully tested in Rohtas Formation. The attribute shows promising and consistent results for identifying Dim Spots in the Rohtas Formation. A comparison between Sweetness Attribute and AFD is also carried out and it is found that newly formulated AFD attribute is more effective to identify Dim Spot (hydrocarbon bearing zones) of Rohtas Formation. This attribute may also be used for identification of Dim Spot reservoirs in high impedance sediments of other basins.

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