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Enhancing the indication of ancient geologic features by using Seismic Attributes technique extracted along picked horizons of seismic and flattened data

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Abstract

Three Seismic Attributes are used to enhance or delineate geologic feature that cannot be detected within seismic resolution limit. These are Instantaneous Amplitude, Instantaneous Phase and Instantaneous Frequency Attributes. These are applied along two defined picked surface horizons within 3D seismic data for an area in southern Iraq. Two geologic features are deduced, the first represents complex channel system at the top of Saadi Formation and the second represents submarine fan within Mishrif Formation. The semblances of these ancient geological features are dramatically enhanced by using flattening technique.

Keywords: Seismic Attribute, Flatting technique, Ancient geological features.

تحسين دلالة تراكيب جيولوجية قديمة باستخدام تقنية الملامح الزلزالية لعواكس ملتقطة عبر بيانات زلزالية ومسطحة

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الخلاصة

تم استخدم ثلاثة ملامح زلزالية لتحسين اوتحديد التراكيب الجيولوجية التي لايمكن التقاطها ضمن حدود القدرة التحليلية للموجة الزلزالية هي السعة الانية، الطور الاني و التردد الاني. هذه الملامح طبقت علي عاكسين ملتقطين ضمن حيز ثلاثي الابعاد لبيانات منطقة تقع في جنوب العراق. استنتجت ظاهرتان جيولوجيتان، الاولى نظام قنوات معقد ضمن اعلى تكوين السعدي، والثانية تمثل مروحة تحت بحرية ضمن تكوين المشرف. مظهر هذه التراكيب او الاشكال الجيولوجية القديمة تحسن بشكل ملفت للنظر بعد استخدام تقنية التسطيح لهذه العواكس.

Introduction

Seismic Attribute is a quantity extracted or derived from seismic data by mathematical transformation [1]. Seismic Attributes may be divided into two categories, which are horizon-based Attributes and sample-based attributes [2]. Seismic resolution limit is defined as the minimum distance between successive reflections. This can be recognized as $\lambda/4$ of signal wave wavelength [3]. So, to

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recognize the subsurface thin geologic features with thickness less than seismic resolution limit, other techniques must be used. Seismic Attribute is one of these techniques used to enhance seismic information which leads to better geological or geophysical interpretation [4]. Some attributes, such as Seismic Amplitude, Envelopes (Instantaneous Amplitude), RMS Amplitude, Spectral Magnitude, Acoustic Impedance, Elastic Impedance, and AVO are directly sensitive to changes in seismic impedance which reflect facies change [5]. 3D Seismic Attributes in many fields are used to clear submarine channels and valleys [6].

The three types of Seismic Attributes with horizon-based attribute category are Instantaneous Amplitude, Instantaneous Phase and Instantaneous Frequency Attributes. Instantaneous Amplitude is used for lithological interpretation and reservoir prediction of seismic data. It is influenced by lithological changes, fluid changes, physical properties, unconformity, strata tuning effect, and stratigraphic sequence changes [1]. Instantaneous Phase Attributes discriminates continuity and geometrical shape [7]. Instantaneous Frequency Attributes handle with suddenly frequency decreases in hydrocarbon reservoir, thus lateral change in frequency can be used to delineate seismic facies [8].

The objective of the current paper is to use advanced interpretation tools (Attributes) to deduce ancient geologic features and enhance the characteristics of their attributes using flattening technique.

Methodology

An analytical signal or complex trace which contents of two parts (real trace in one plain and the imaginary trace perpendicular to it) treats a seismic trace $f(t)$ as the real part of complex trace, $F(t)=f(t)+jf^{*}(t)$ [9]. The real component is the record trace $f(t)$, and the imaginary component (Hilbert transform) is the quadrature trace, $f^{*}(t)$, which is the real component rotated by 90º.

The seismic amplitude at time "t" (seismic trace) of $f(t)$ is equal to::

$A(t)\ cos\theta(t)$

Where:

$A(t)$: Reflection strength at time "t"

$\theta(t)$: Instantaneous phase at time "t"

and the quadrature trace, $f^{*}(t)$ is equal to::

$A(t)\ sin\theta(t)$.

Now the amplitude is a vector composed of two components, the real and imaginary part of the full seismic trace [10]. The actual seismic trace and the quadrature trace are used to derive a series of seismic attributes called Instantaneous Attribute traces (Instantaneous Amplitude, Instantaneous Phase and Instantaneous Frequency). These attributes are always displayed in color. These attributes are now a familiar facility on most seismic workstations [11], it derived as:

$A(t) = [f^2(t) + f^{*2}(t)]^{½}$

$\theta(t)=tan^{-1}[f^{*}(t)/f(t)]$

and

$w(t)=d\,\theta/dt$

Where:

$A(t)$: Instantaneous Amplitude

$\theta(t)$: Instantaneous Phase.

$w(t)$:Instantaneous Frequency which represents the rate of change of time-dependent phase [9].

Sometimes the envelope or reflection strength is referred to as "Instantaneous Amplitude', "Amplitude Envelope" [10].

Attributes may be measured (extracted) along picked surface horizon or in a horizontal section called "time slice" within seismic data volume.

The problem

Instantaneous Amplitude Attribute (IAA), Instantaneous Phase Attribute (IPA) and Instantaneous Frequency Attribute (IFA) are applied to 3D seismic data in an area located in southern Iraq using CGG Hampson-Russell program Ver.9.0. This Attributes are extracted along two picked surface horizons. The first is at top of Saadi Formation (carbonate rocks with shale layers present in the upper part of this formation. These shale layers are absent in neighbor fields [12]) Figure-1. The second is within the Mishrif Formation (35 msec below top of Mishrif Formation) Figure-2. Mishrif Formation is composed of carbonate rocks with few percentages of shale and dolomite. Deposition facies of this formation are divided into five facies, one of these is shallow outer shelf in the middle and lower part of the formation [13]. Figures-3 and -4 are showing the IAA applied for both Saadi and Mishrif reflectors. The first shows a channel/levee system Figure-3, while the second reflect a submarine fan Figure-4. Actually, this is not an easy task to find such type of features. It is need an accurate picking and care process for pre-stack and post-stack data.

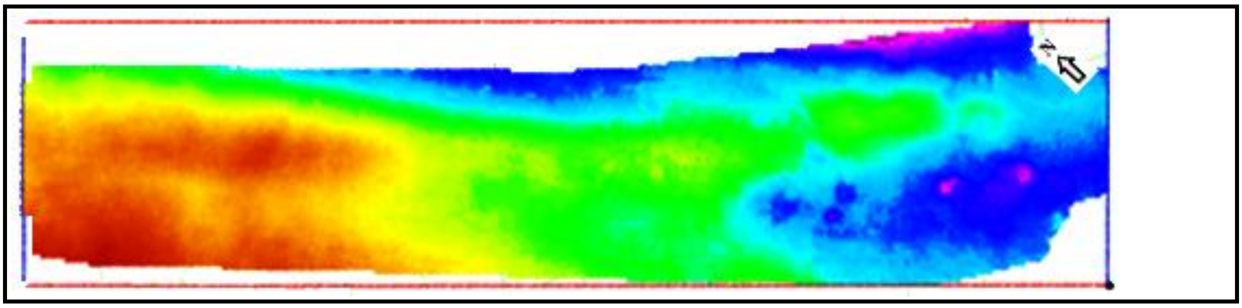

Figure 1-Seismic time slice extraction of Picked Saadi Formation.

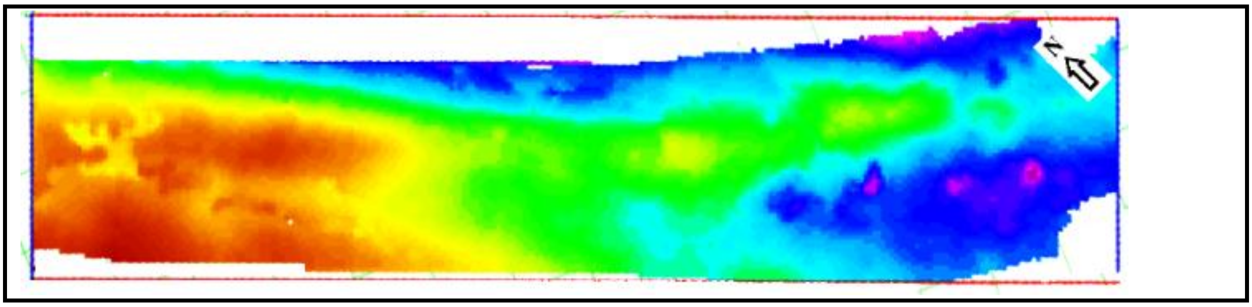

Figure 2- Seismic time slice extraction of Picked Mishrif Formation.

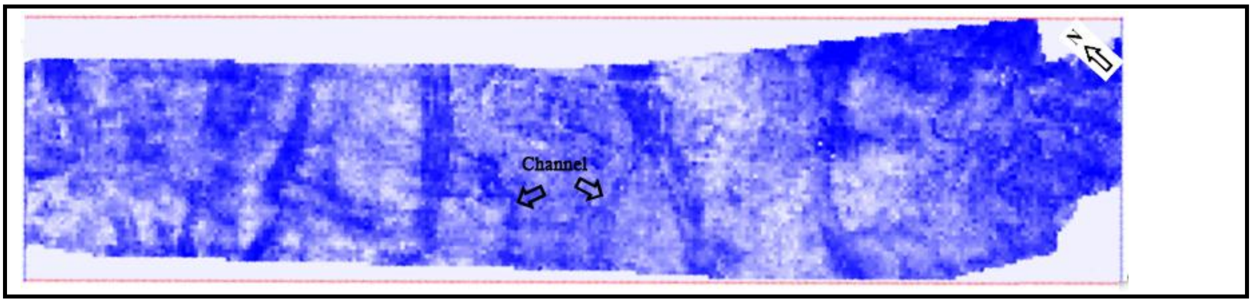

Figure 3- IAA extracted along picked top Saadi Formation by using CGG 9.0 program.

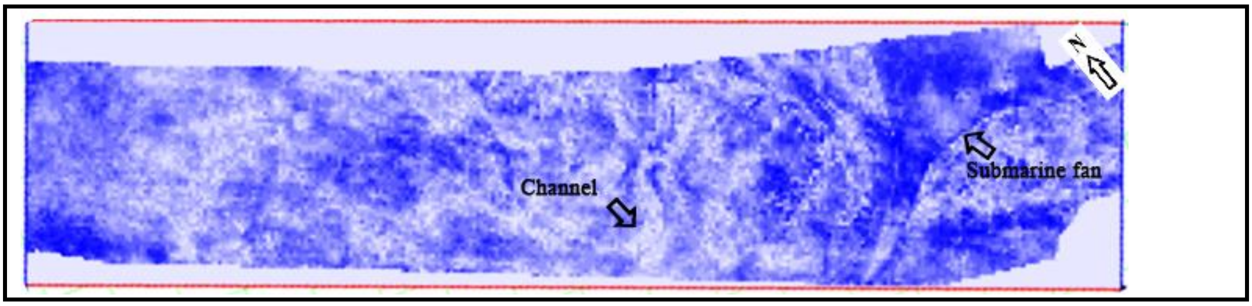

Figure 4- IAA extracted along 35msec below picked top Mishrif Formation by using CGG 9.0 program.

The problem here is how to try to connect both ancient geological features that have different time locations with some dipping toward the southeastern part of the area and how to enhance the track of these ancient geological features. Flattening technique or stratal slicing can solve this problem using CGG Hampson-Russell program. The process by which a seismic volume is flattened with reference to an interpolated, continuous 3-dimensional surface (lithologic boundary, disconformity, condensed section, etc.), is defined as a horizon, known as “stratal slicing”. Although, much information can be ascertained from such an extraction, the process of stratal slicing is a much preferred method for revealing the stratigraphic nature of an interval being studied, because it removes the variation of seismic attributes (e.g., amplitude) across different strata. This unique approach was introduced into industry in the late 1990's by Dr. Hongliu Zeng [14, 15], then a Research Scientist for the Bureau of Economic Geology at the University of Texas, in Austin.

The strata-grid makes the "interactive" possible, not only for visualizing the data, but also for quantitatively analyzing attributes for large 3-D seismic surveys – without handling the whole data volume [16]. The idea of stratal slicing is simple, the Principle of Original Horizontality, depositional sequences are laid down in a horizontal manner. Since an interpreted horizon is a representation of a coeval 3D surface, its nature is to undulate in space as it follows the wavelet pick from trace to trace (trough to trough, (+/-) zero-crossing to (+/-) zero-crossing, or peak to peak) Figure-5.

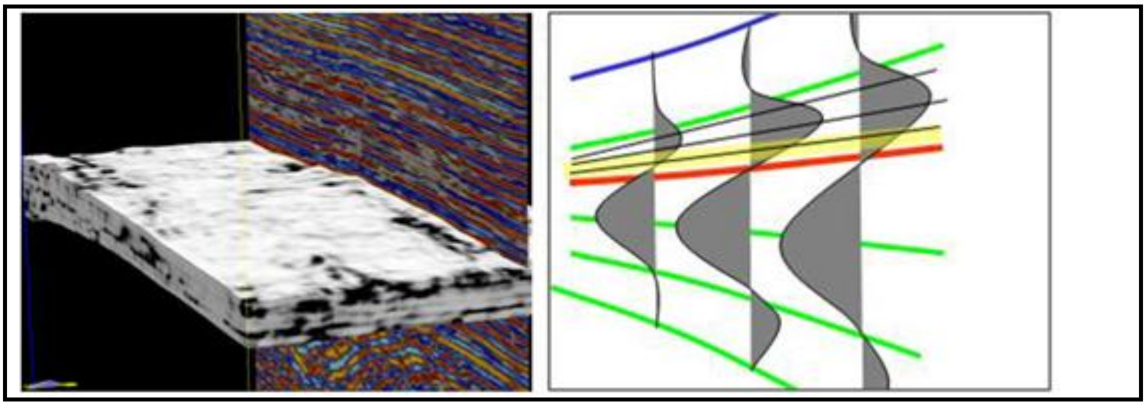

Figure 5- The concept of stratal slices and their associated attribute extractions along adjacent traces [16].

Stark [17] defined the slice through an attribute cube following a constant relative geological age surface as a strata-slice. These types of slices can be scrutinized for the presence of stratigraphic/depositional features. The time sampling of 2 ms for seismic surveys is beyond the seismic resolution and several slices are captured within a single seismic loop. Subtle variations in loop shape are hence resolved by this strata slicing technique. Flattened horizon displays often illustrate sedimentary features quite nicely Figure-6.

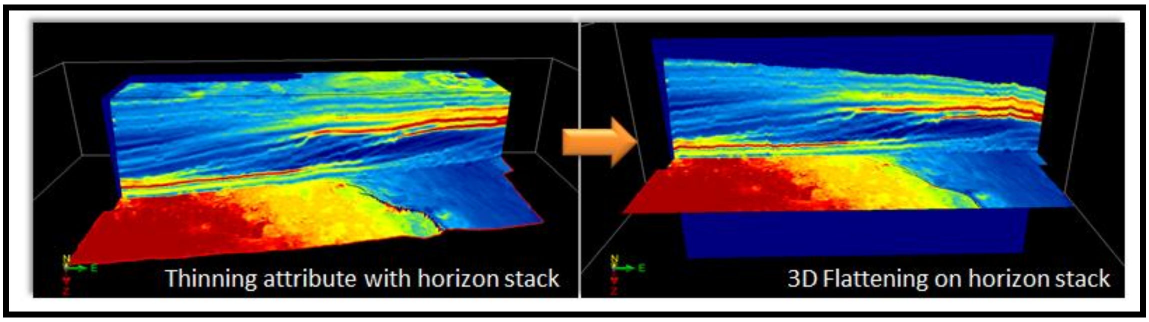

Figure 6- Illustrate a Flatten horizon display.

The processing procedure that has been depended in the present work is shown in Figure-7.

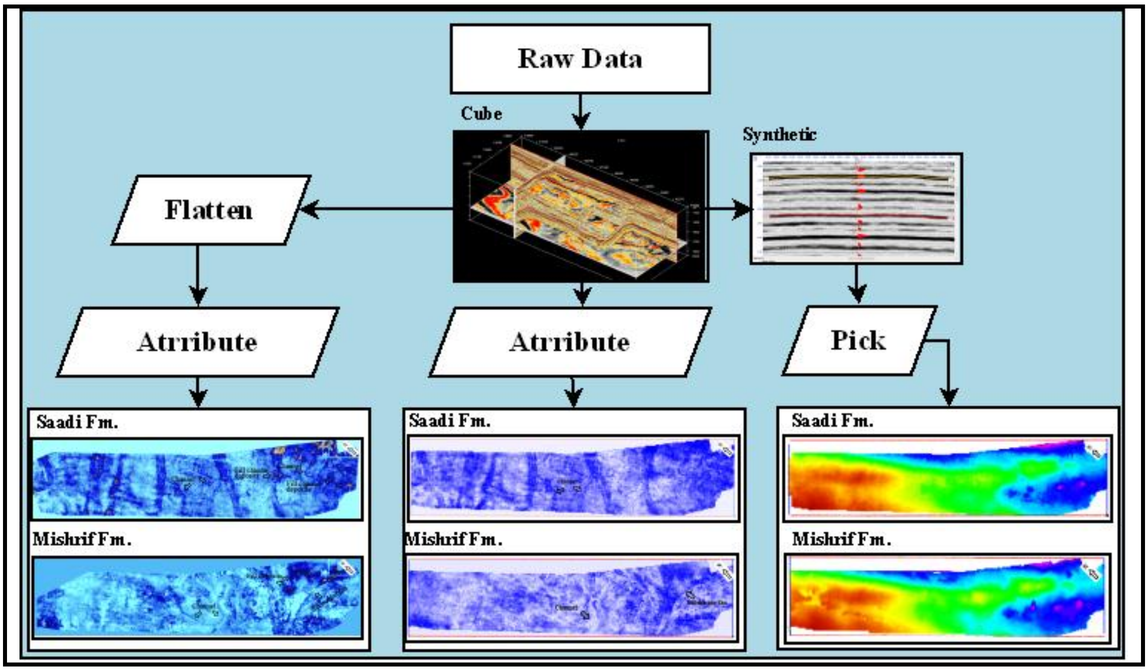

Figure 7- A flowchart for the procedure of the current work.

Figures-8 and -9 are showing the flattening results with reference to top of Saadi Formation. Many details became clearer than that on 3D seismic data at the same level of picked surface horizons Figure-3 and -4. The semblance of channels and submarine fans are shown concordantly in their continuity, shape, and resolution. Many locations in Figure-8 and -9 are showing area of dark colours. These areas are representing fill deposits with low frequency which may indicate fluid presence.

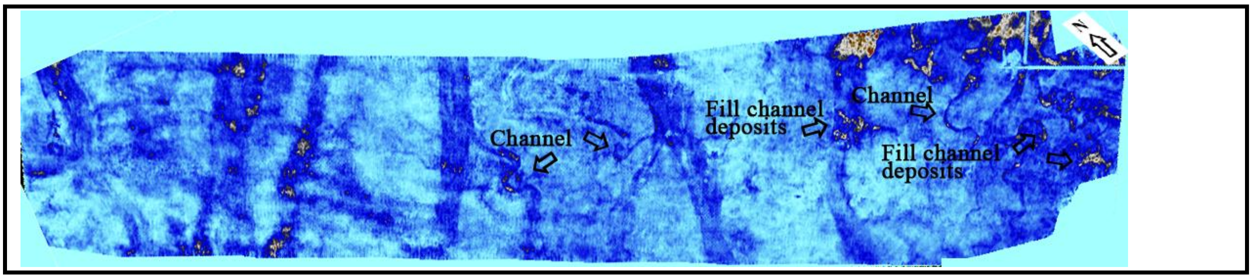

Figure 8- Flattened IAA extracted along 3D seismic data at picked Saadi Formation showing much more internal details with regard to the channel's continuity.

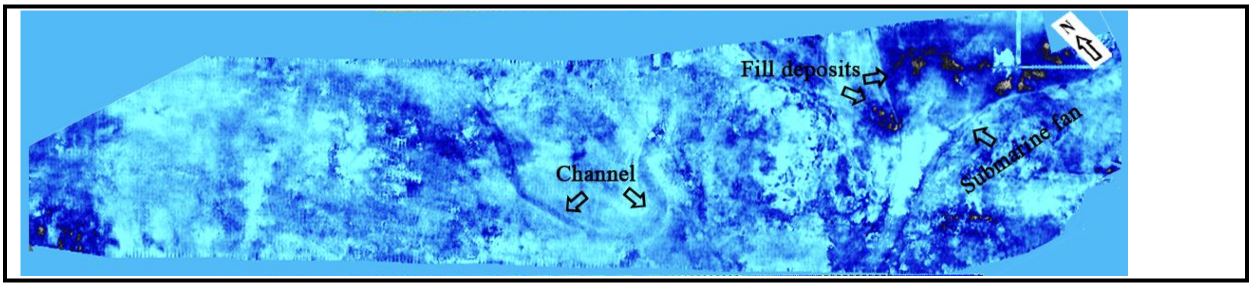

Figure 9- Flattened IAA extracted along 3D seismic data at 35msec below picked top Mishrif Formation showing much more internal details with regard to the channel's continuity and submarine fan.

Trying to follow these geological features in the real seismic section to evaluate the contribution of the applied flattened attribute in enhancing the diagnostics of them, a comparison images is made between attributed image on the left and different types of seismic section on the right Figures -10, -

11, -12, -13 and -14. Arrows are placed in both figures to define the point location of comparison where both have the same time. Figures -10 and -11 are showing conventional shape of channel on seismic section but in Figure 12, it seems impossible to extract the channel from seismic section and the extracted IAA resolve this problem.

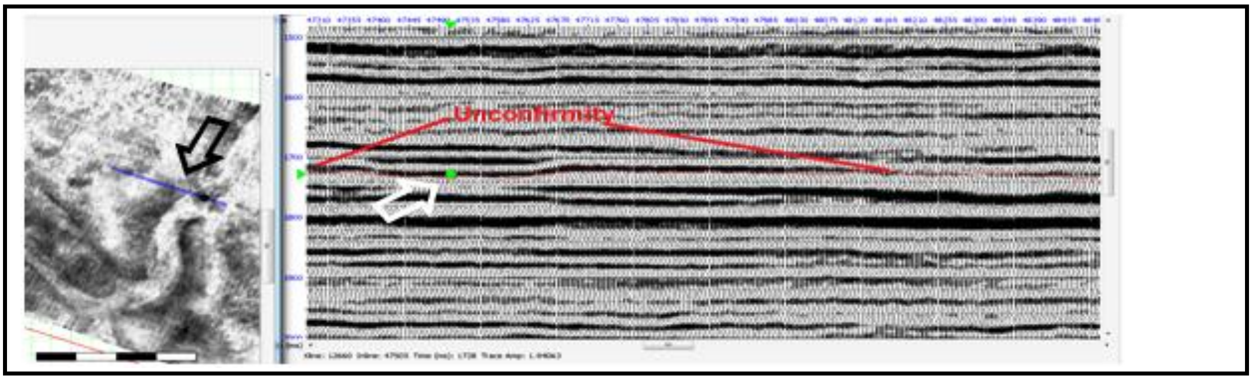

Figure 10- A track is taken across IAA image for selected part of the study area (left) compared with its seismic section. A conventional shape channel is clear on seismic section.

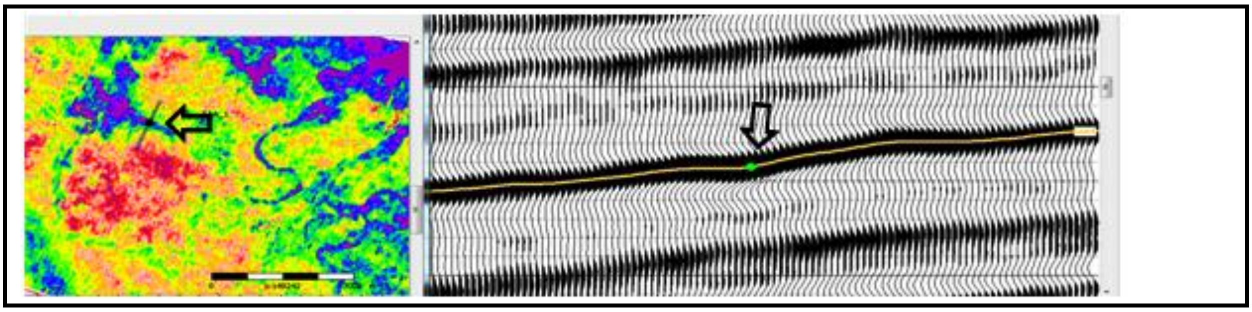

Figure 11- A track is taken across IAA image (colored scale) for selected part of the study area (left) compared with its seismic section. The location of channel on seismic section is distinguished clearly.

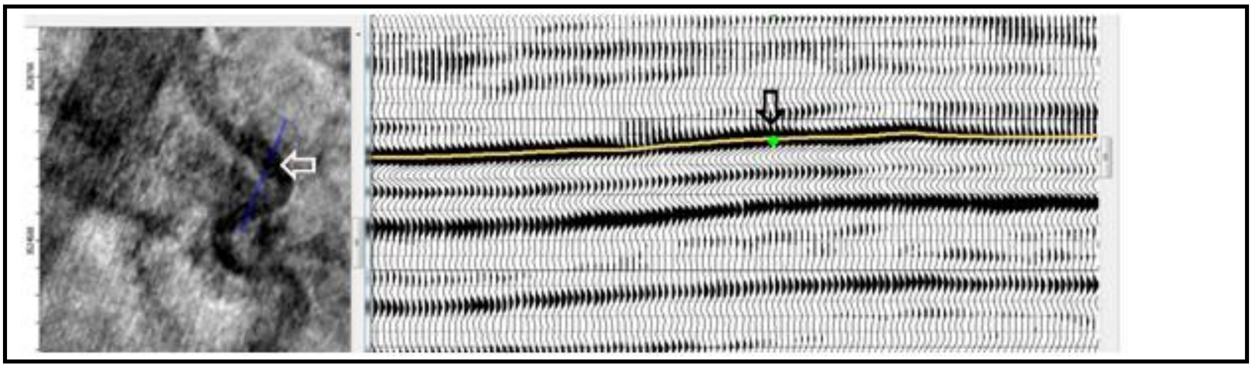

Figure 12- A track is taken across IAA image for one of the channel in the study area (left) compared with its seismic section. The location of channel on seismic section is very difficult to be distinguished while its shape is clear in IAA image.

Figure-13a is representing a clear shape and continuity for submarine fan on the IPA image (left) and the colored seismic section (right) which is defining the edge location of this geological feature. The present case Figure -13a can be compared with an excellent example of submarine fan system given by [18] Figure-13b.

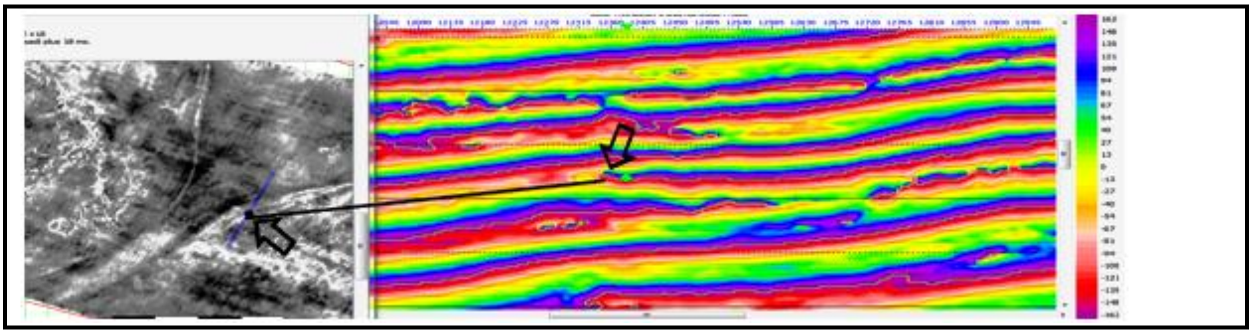

Figure 13a- A track is taken across IAA image for the part of submarine fan area (left) compared with its colored seismic section IPA. The edge location the progradation pattern continuity for submarine fan is distinguished in the seismic section.

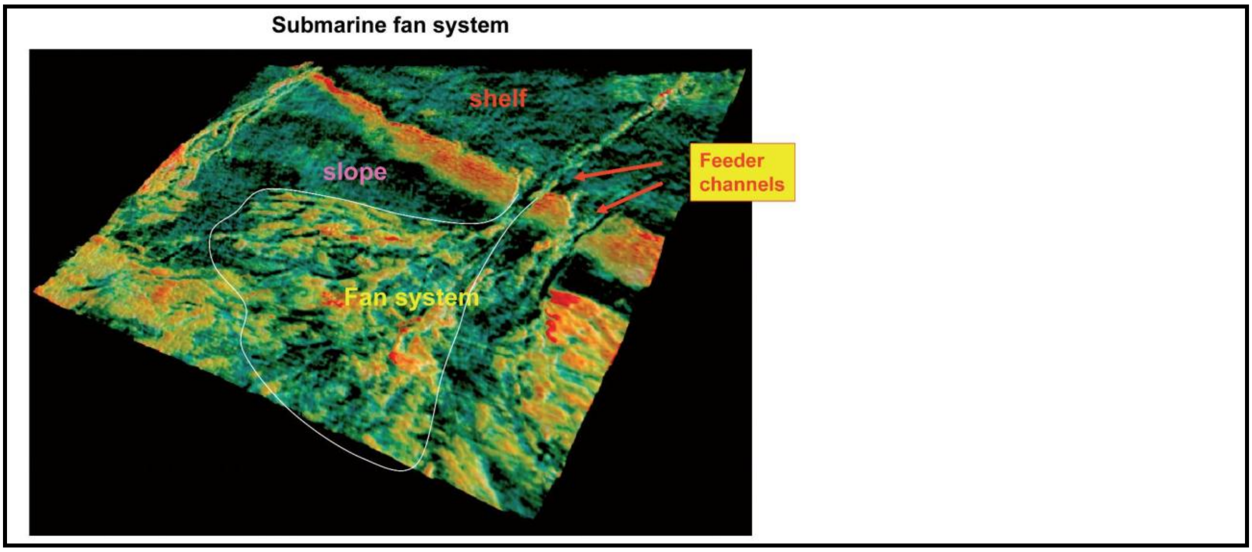

Figure 13b- Submarine fan system modified from (Dr. H. James of ParadigmGeo) after [18].

The IFA section (right) in Figure-14 shows high frequency with base channel while fill deposits with low frequency which may be indicate fluid presence.

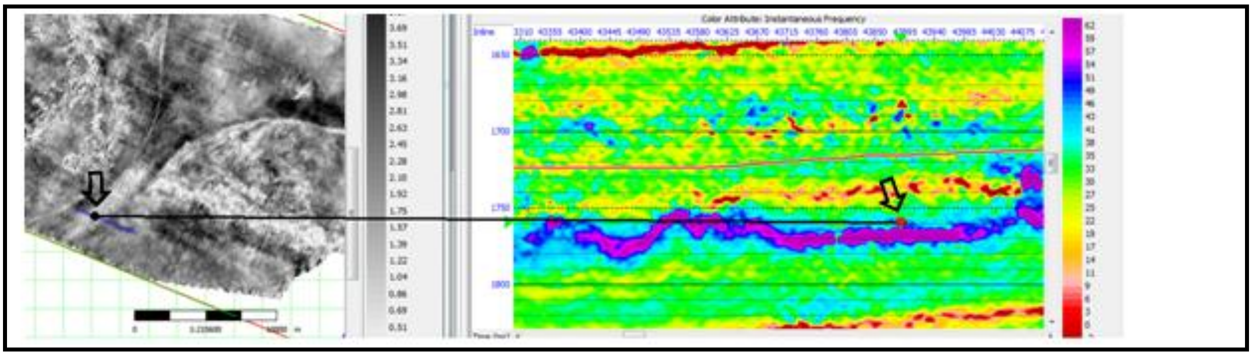

Figure 14- A track is taken across IAA image for the part of submarine fan area (left) compared with its coloured seismic section IFA. The IFA clears feeder channel base with high frequency and fill deposits with low frequency.

Results and Discussion

The results of the present study has prove that, seismic attribute along flattened data have the ability to enhance the criteria of characterization (visualization, resolution, shape and continuity) for thin geological features such as stratigraphic/depositional features and give better image than horizontal section (time slice) and defined pick surface horizon (horizon slice). IFA gives an indication for a clear agile facies change in seismic section vertically and horizontally. Meanwhile, the

IPA gives advantageous way for representing the reflection shape of these ancient depositional features.

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