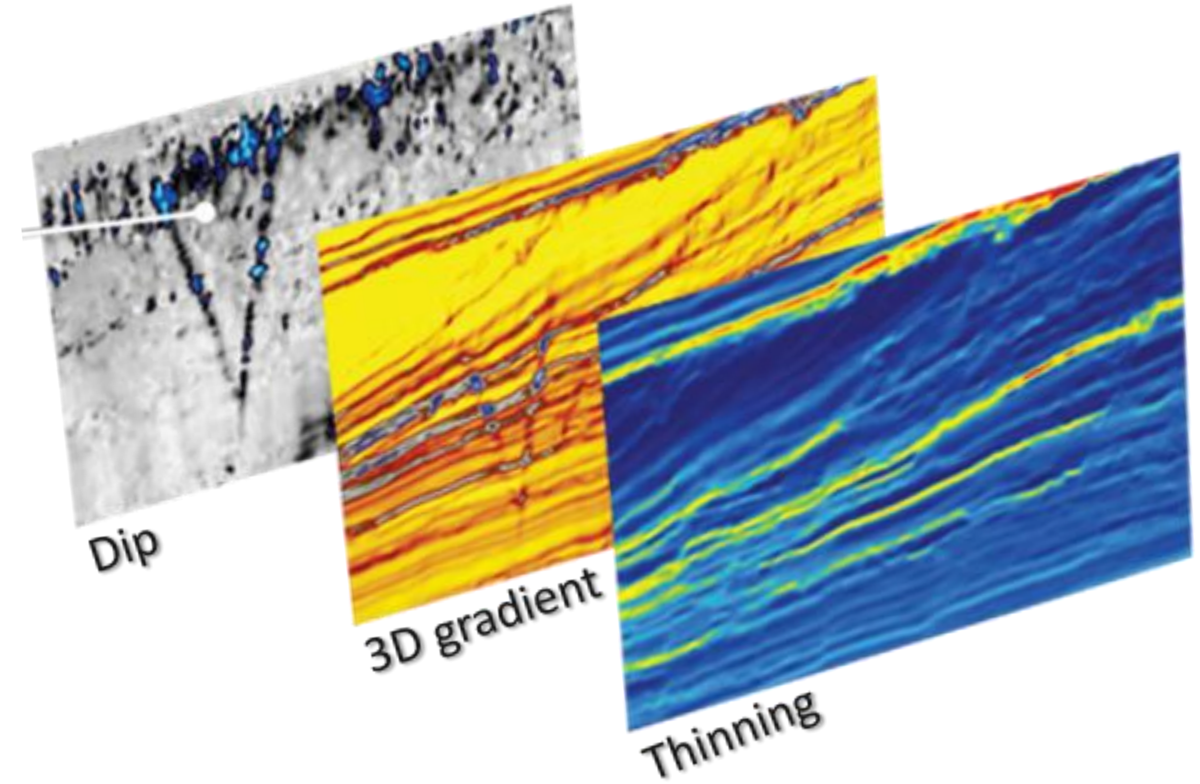

Subsurface Structure and Feature Identification, Rock Properties Analysis, and Depositional Environment Delineation Through Advanced Attribute Analysis

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Petrel
Shared earth—critical insight

Consistent Dip….??

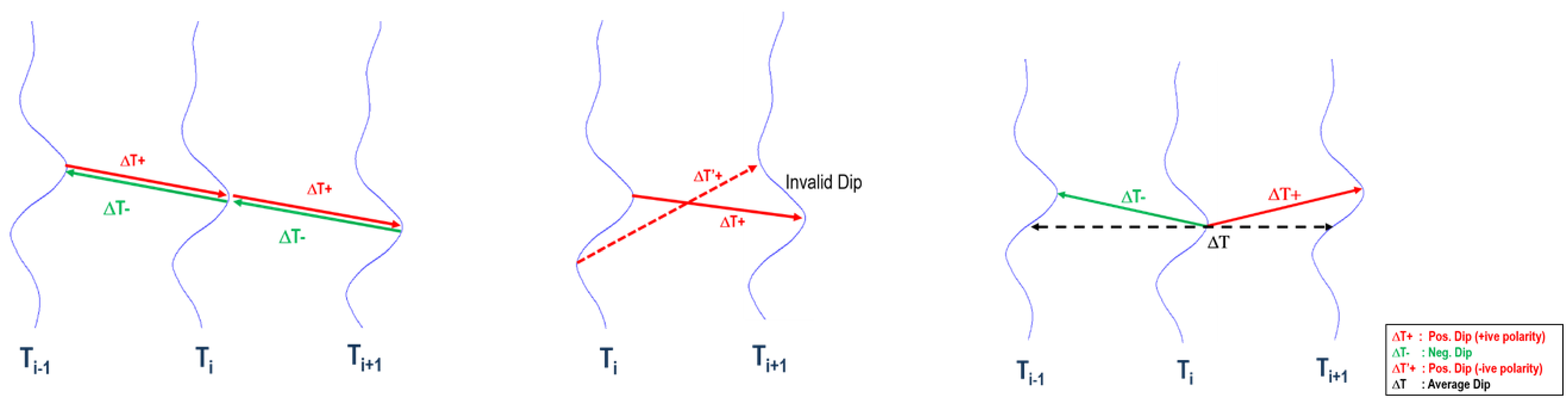
- Consistent Dip provides a very precise Volumetric Dip estimation and the dip fields is stored in the correct unit. It is very significant for many structural attributes as better dip estimates give better structural attributes.
- In traditional methods (Cross correlation or gradient based eigen value) apply smoothing filter which reduce the lateral and vertical resolution. On the other hand, consistent dip use an iterative global optimization method to calculation dip.
- Another critical aspect of Consistent Dip estimation is that it operates in Cartesian coordinate system(X,Y,Z) for the correct computation of dips rather than IJK space (Image coordinate system) which works on a basic assumption that seismic samples are equidistant in all three dimensions. Therefore IJK is not most suitable domain, because seismic samples do not always have the same extents in each dimension.
- The properties of consistent dip are; reciprocity, causality, consistency and continuity.

    Reciprocity : symmetry in the estimate of seismic dips between neighboring traces

    Causality : Maintaining the relation between a cause and an effect

    Continuity :In discontinuities a robust method should not try to estimate the dip, , but instead the method should output a byproduct (residual dip or dip quality attribute) which highlights the area of uncertainty

    Consistency : Confirm smooth location for each estimated dip and make a consistency between inline and crossline sample at any arbitrary point.



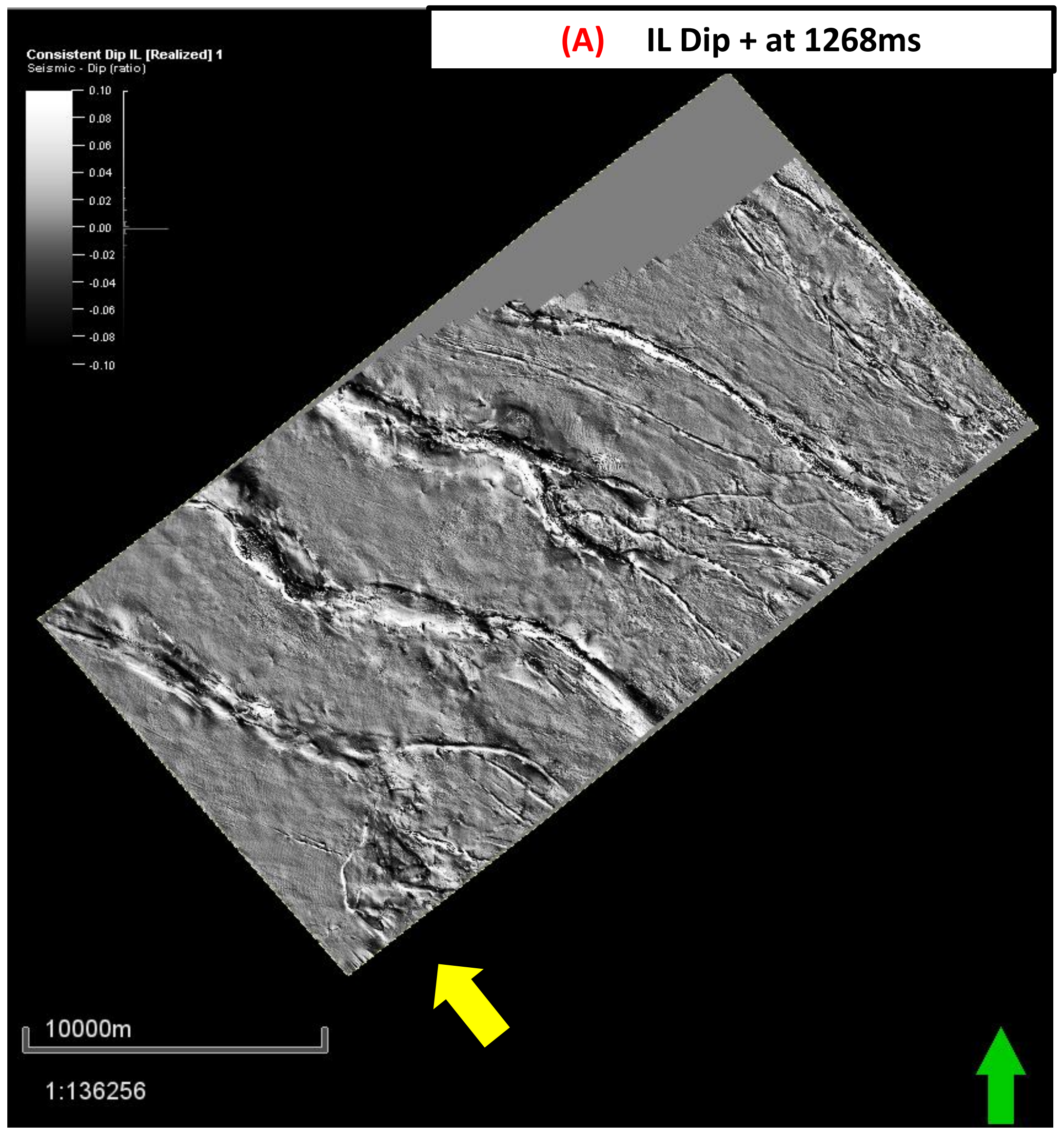
a) Reciprocity

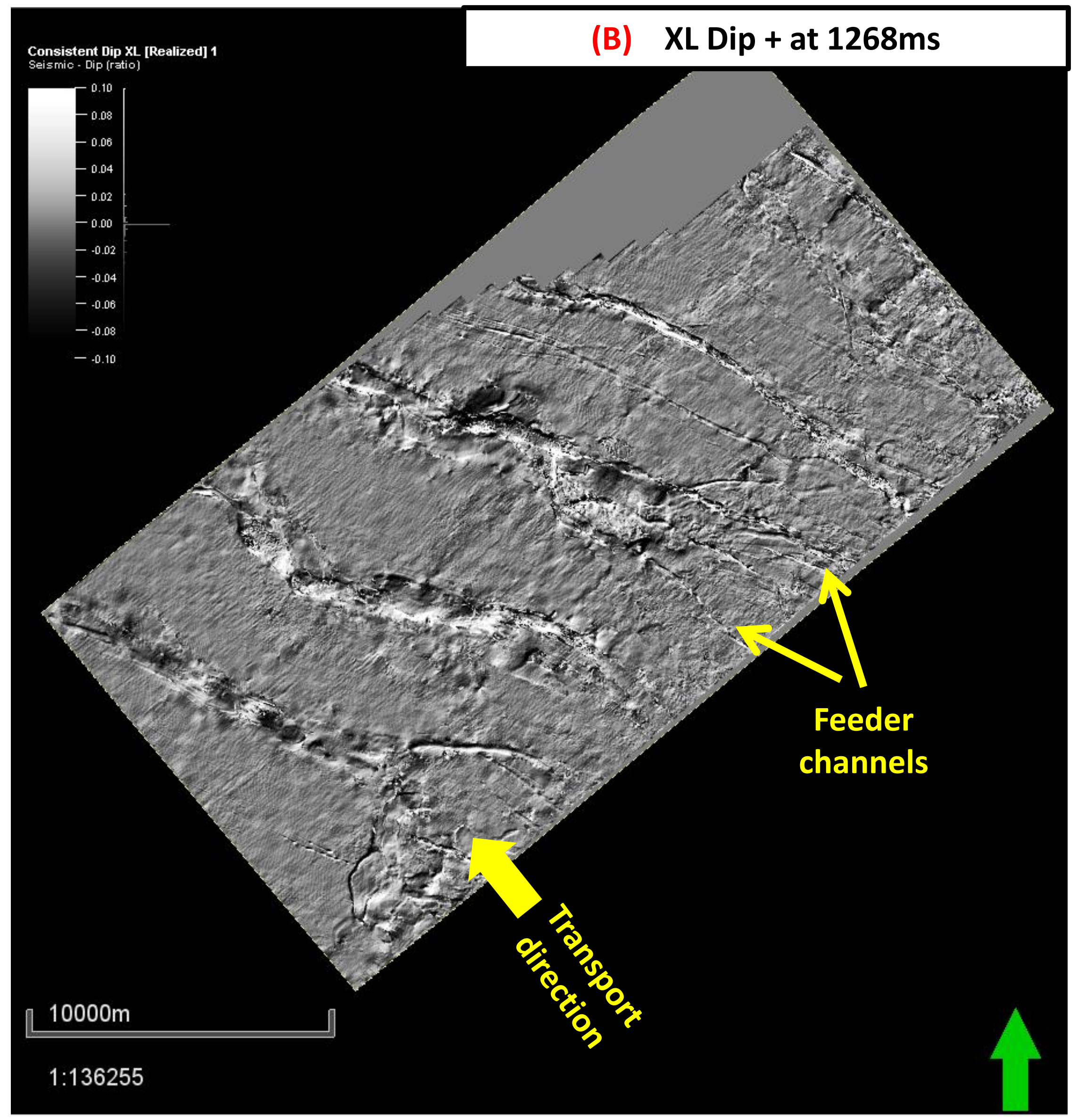
b) Causality

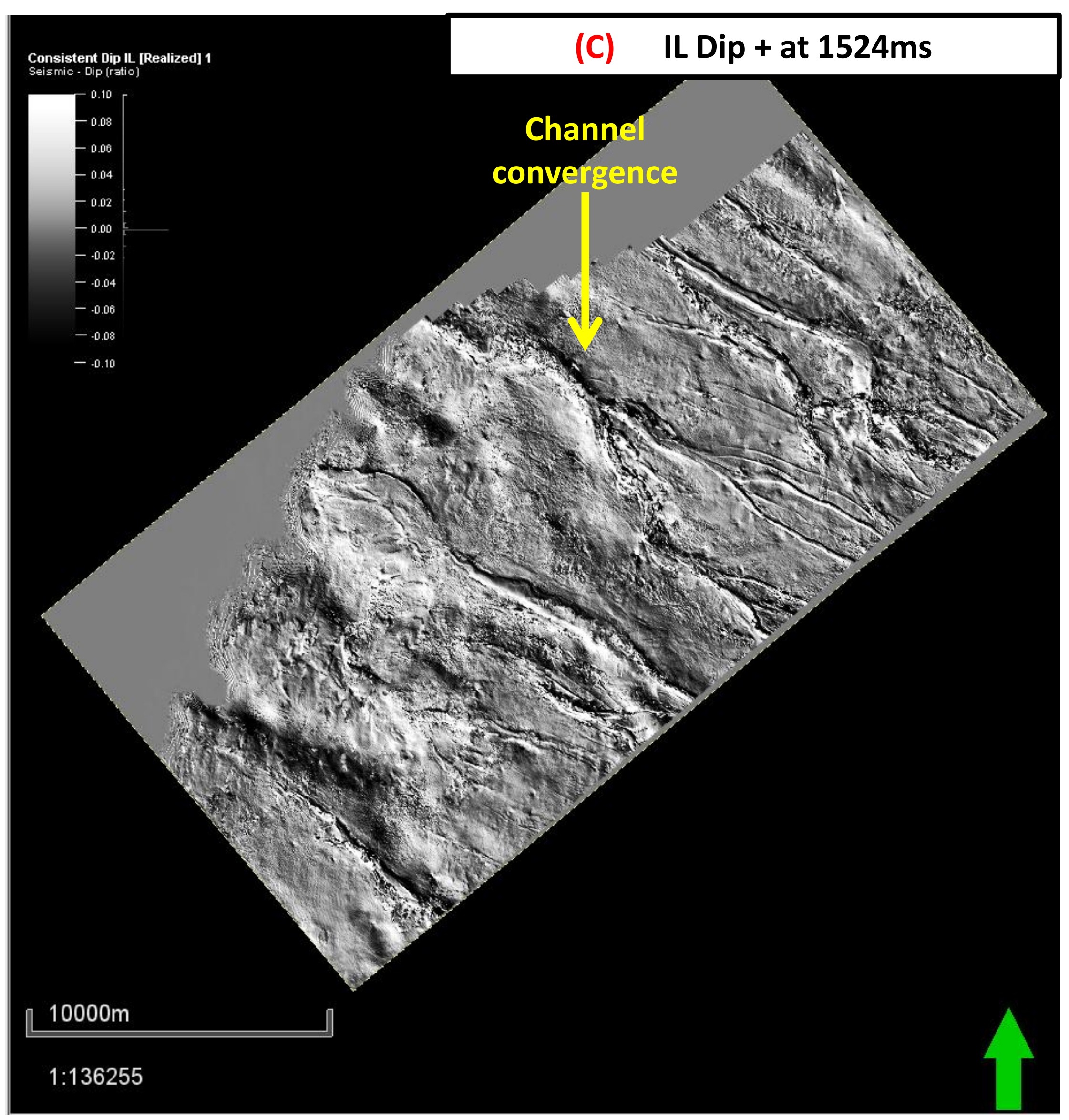
c) Surface Reconstruction

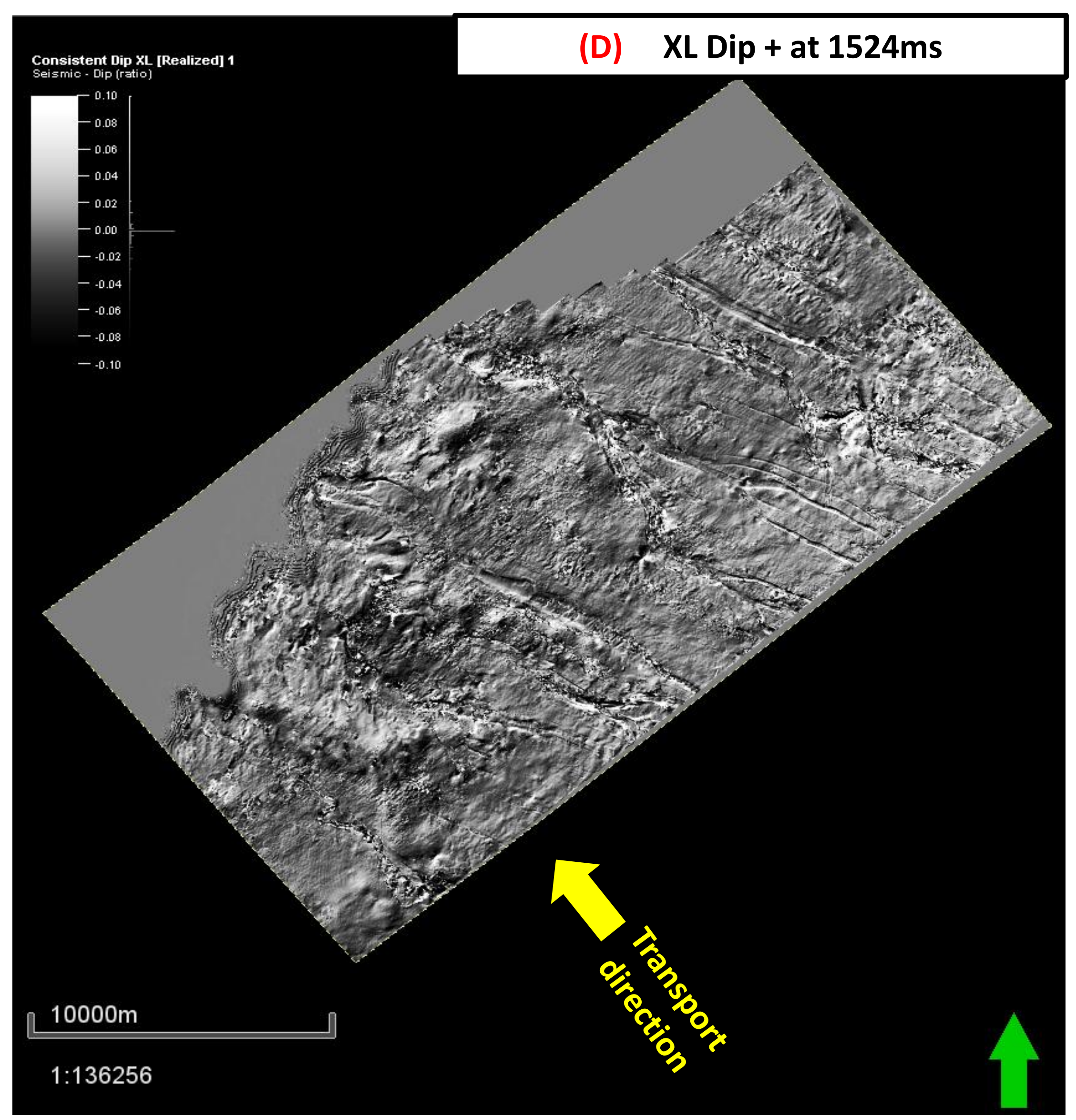
Figure 1. Shows the schematic of global consistency constraints which Consistent Dip honors

Consistent Dip….??



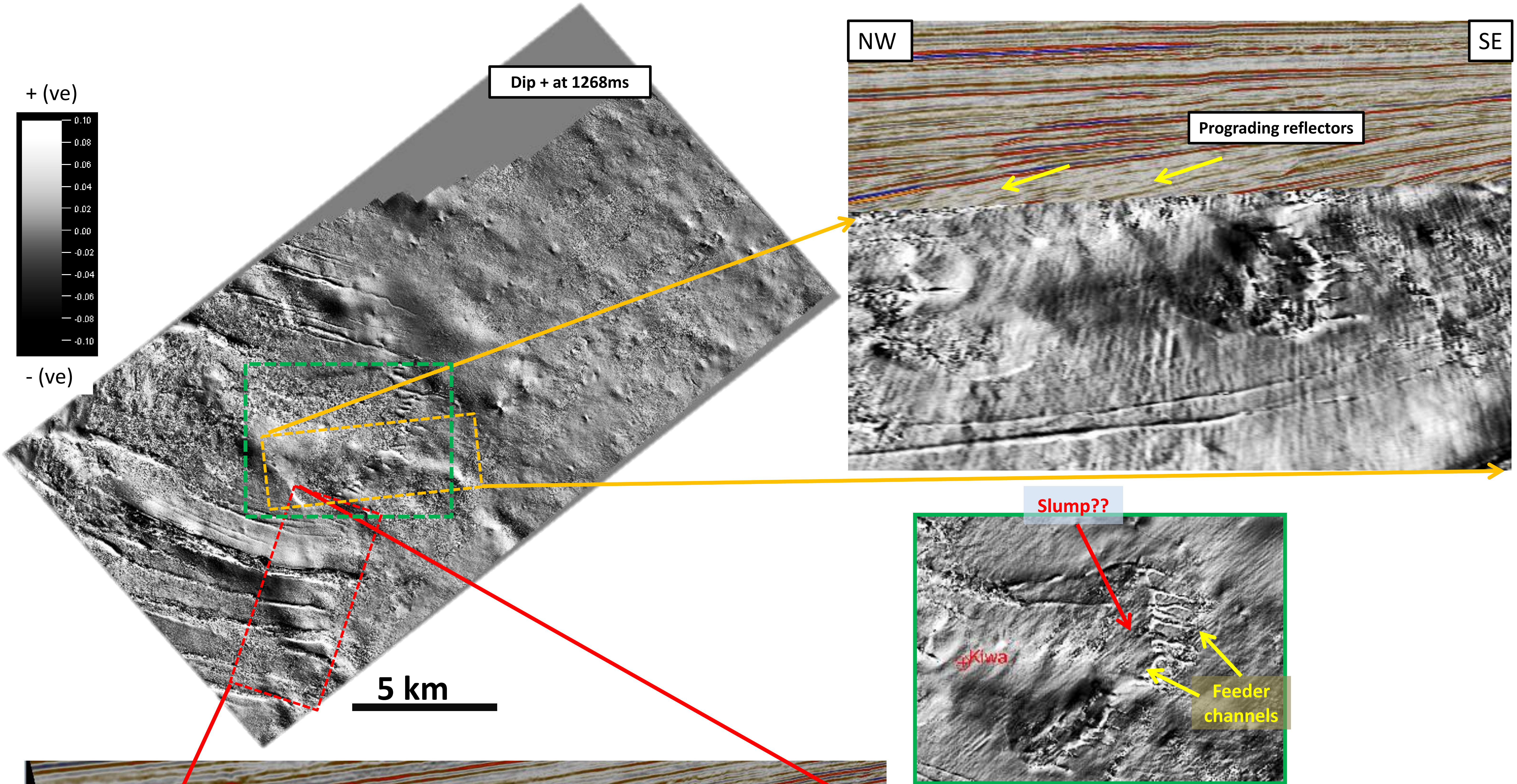


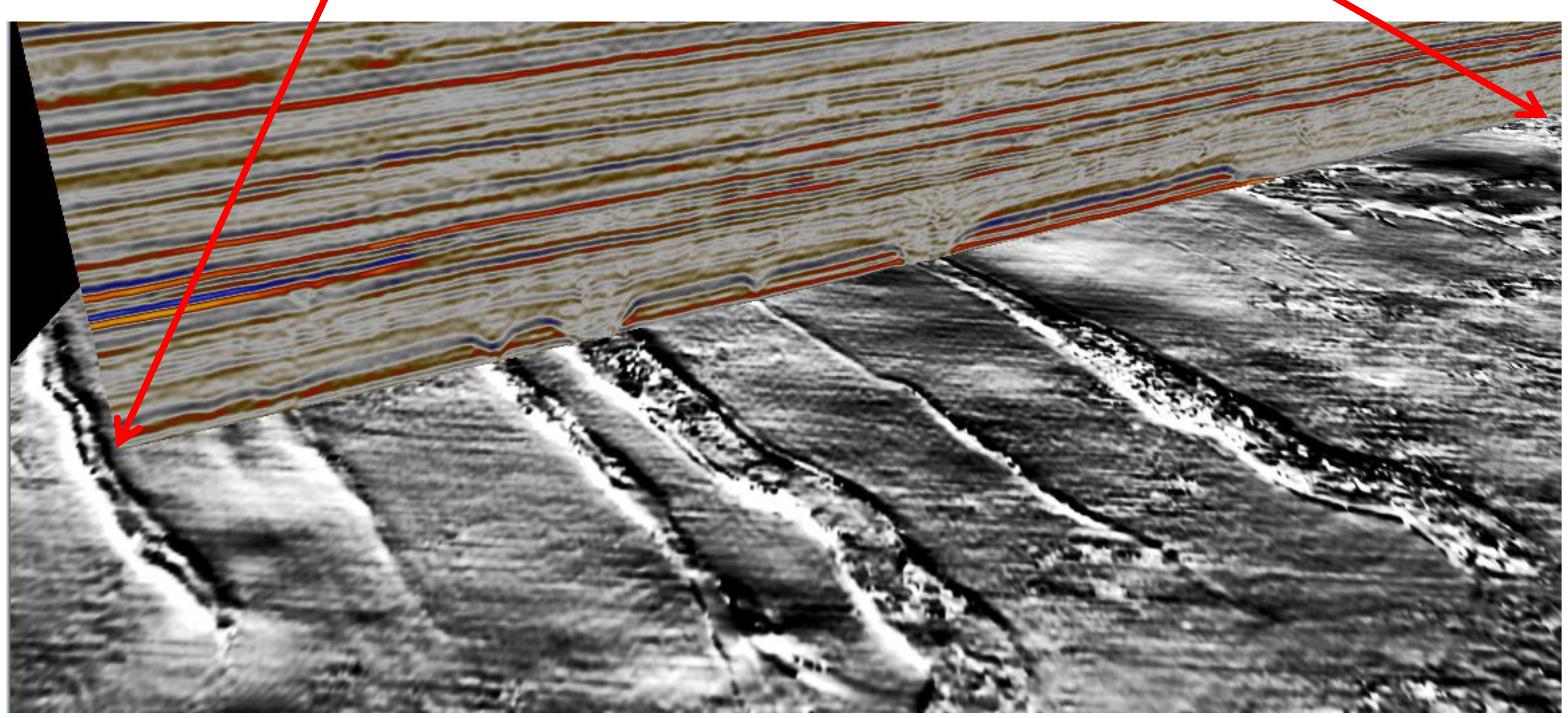




- For this exercise we used output type is Inline and crossline dip. Inline dip is the average of inline positive and negative dips while Crossline dip is the average of cross line positive and negative dips.
- This attribute shows satisfactory results delineating channels and different tributaries. Channel boundaries are also imaged well giving idea on channel width and channel geometry.
- Results show that the channels' geometry changes temporally but transport direction from SE to NW remains constant.
- Comparing between two outputs Inline dip has provided more clear features than Crossline dip.
- The following page will highlight features observed from the timeslice and sediment transport direction.

Consistent Dip....??





- In time slice, look at the green enclose features it may seem that transport direction NW to SE. But combine vertical section (prograding reflectors) it has proved that direction is SE to NW. and the observing fan shape may be slump failure??

- However, the general transport direction somewhat deviates looking at different time slice, but general direction of SE to NW remains constant. This happens because the orientation of feeder channels deviate through time.

Dip Illumination….??

- A good dip estimation can reveal a lot about various structural geology in seismic. Such things as discontinuities (faults) and noisy areas (salts domes), can easily be seen with a good dip estimate and a correct exploitation of the dip values. Dip Illumination attributes highlights the structural geology with the use of lighting and a dip field estimation. This attribute uses a new dip estimation method and displays the calculations in two different views.

- Dip illumination uses a cross correlation dip estimation method that has been modified with gradient decent to accelerate computations.

- Calculation of Dip Illumination provide a option to specify the direction to in which steering will be performed. The resulted direction is in degrees and the dip in magnitude.

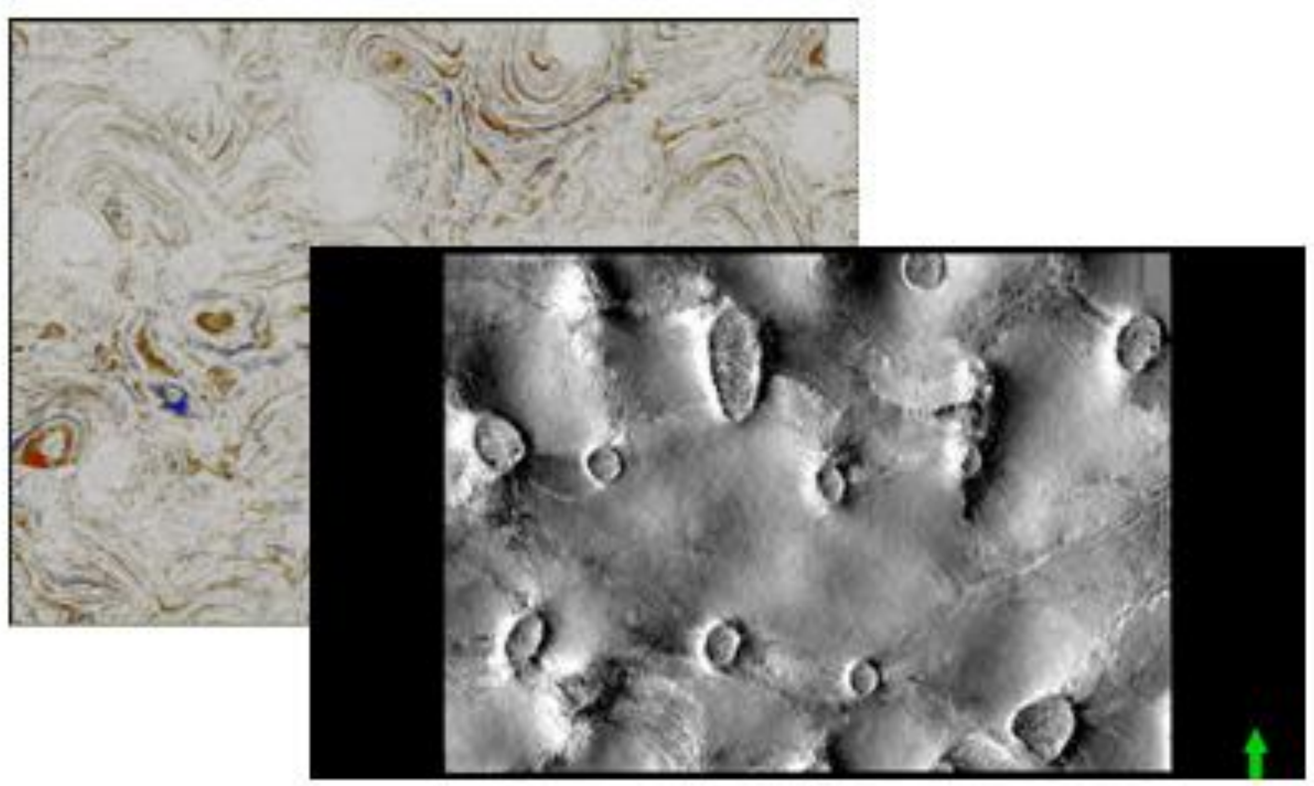
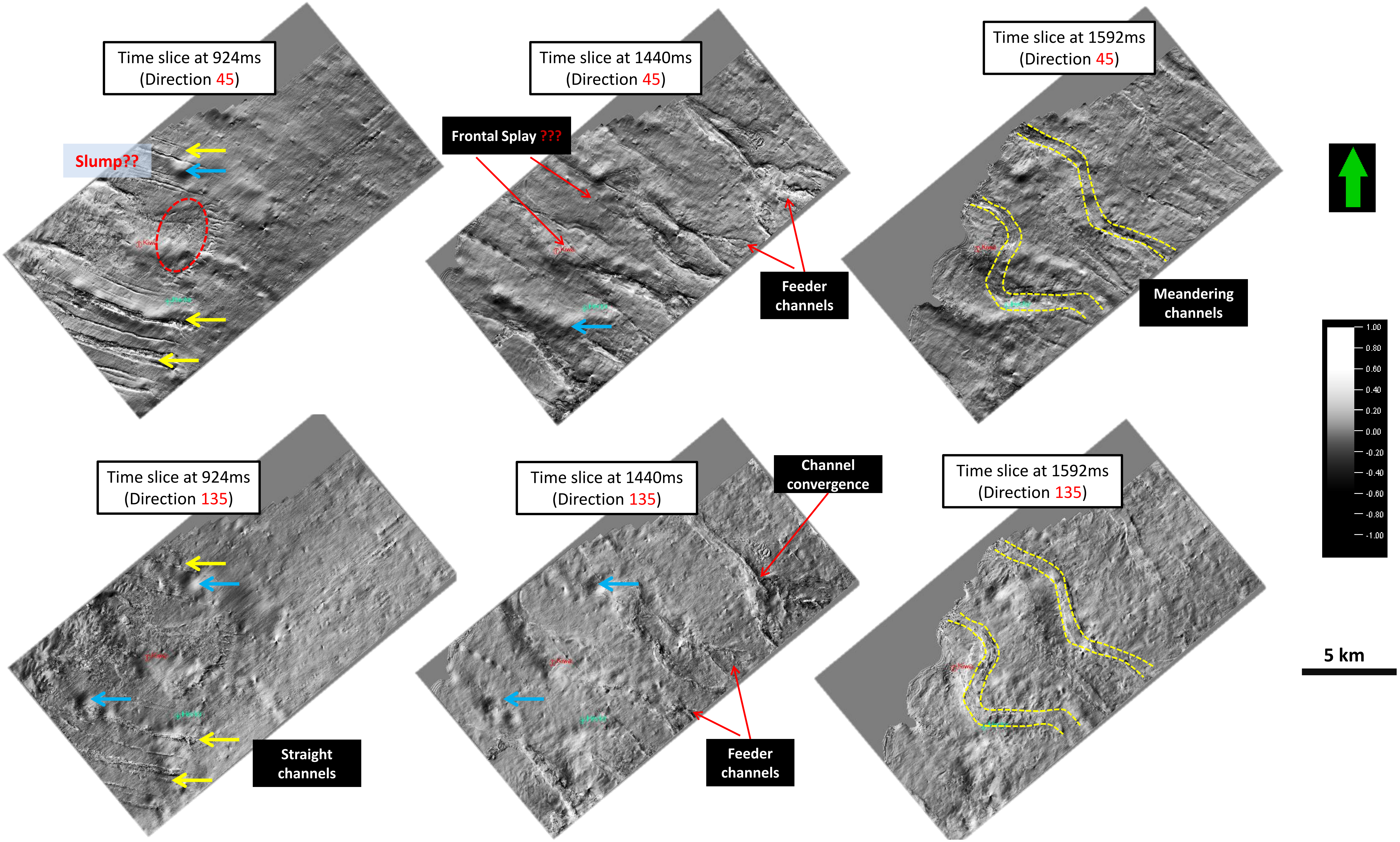


Figure : original time slice (back) and Dip illumination attribute slice (front).

Dip Illumination



- The Illumination attribute for 45 degree direction view shows the channel features in concave geometry. Conversely 135 degree direction view of calculated dip in channels are convex shape.
- 45 degree view is comparatively more clear than the 135 degree view.
- Concave and convex round shape is response to chaotic reflectors.

GLCM….??

GLCM (Gray Level Co-occurance Matrix) is a matrix transformation of the frequency in which different combinations of voxel amplitude values occur. The GLCM has dimensions n*n, where n is the number of gray levels which refers to the dynamic range of the data.

Computing GLCM textural attributes at one location localized features at that point (Chopra and Marafut, 2007). The amplifying geological features by GLCM such as mass transport complexes, channels, and dewatering structures that have lateral patterns that exceed mere edges.

Four parameters need to be defined upon constructing GLCM: the quantization level of the image (levels), the size of the moving window (lateral-&-vertical window), the direction and distance of voxel pairs (split), and the statistics used as a texture attribute (algorithm).

The parameters are divided into five main categories, which directly relate to the required factors above;

Algorithm: Selects the GLCM equations used to calculate the statistic based upon the co-occurrence matrix.

amplitude limit: Selects the portion of the data to be saturated on the lower and upper ends.

Levels :Controls the number of gray levels or levels of quantization in the definition of the co-occurrence matrix (figure, 2).

Split :Defines the distance between reference and samples used to calculate the co-occurrence matrix.

Lateral/Vertical radius: Defines the moving window (figure 1)

Petrel help menu & Chupra and Maraful, 2007

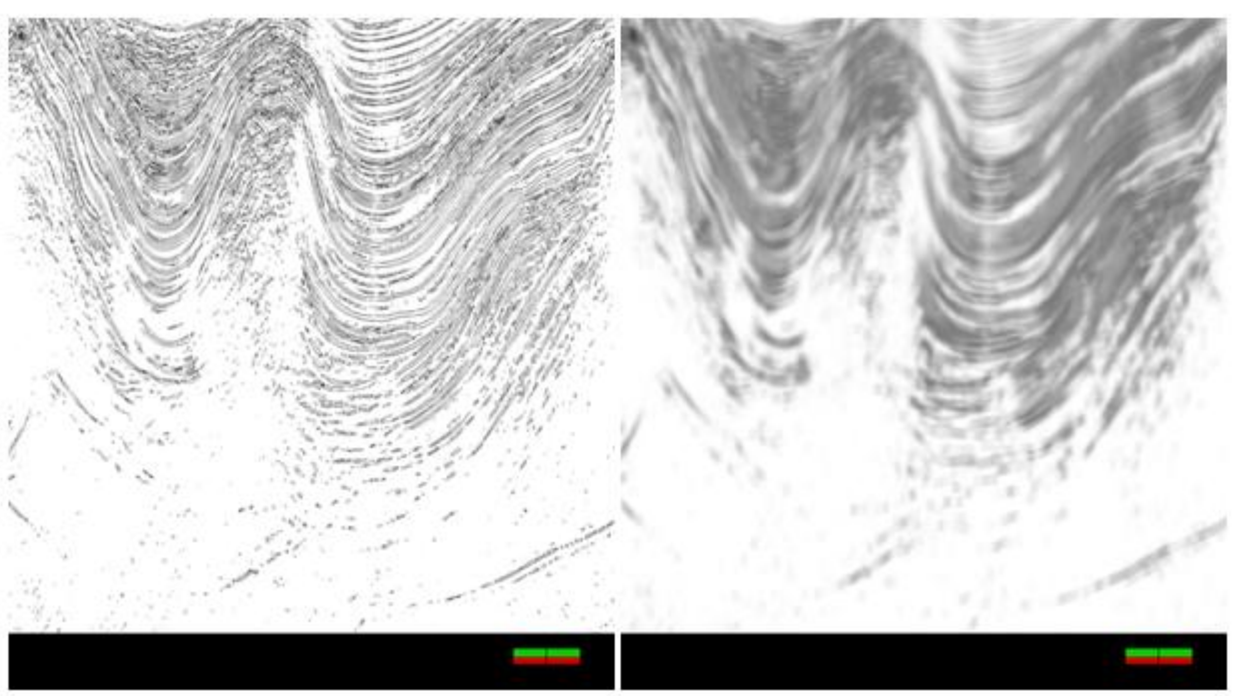


Figure 1: Difference between a low lateral and vertical window and a high window (Petrel help menu).

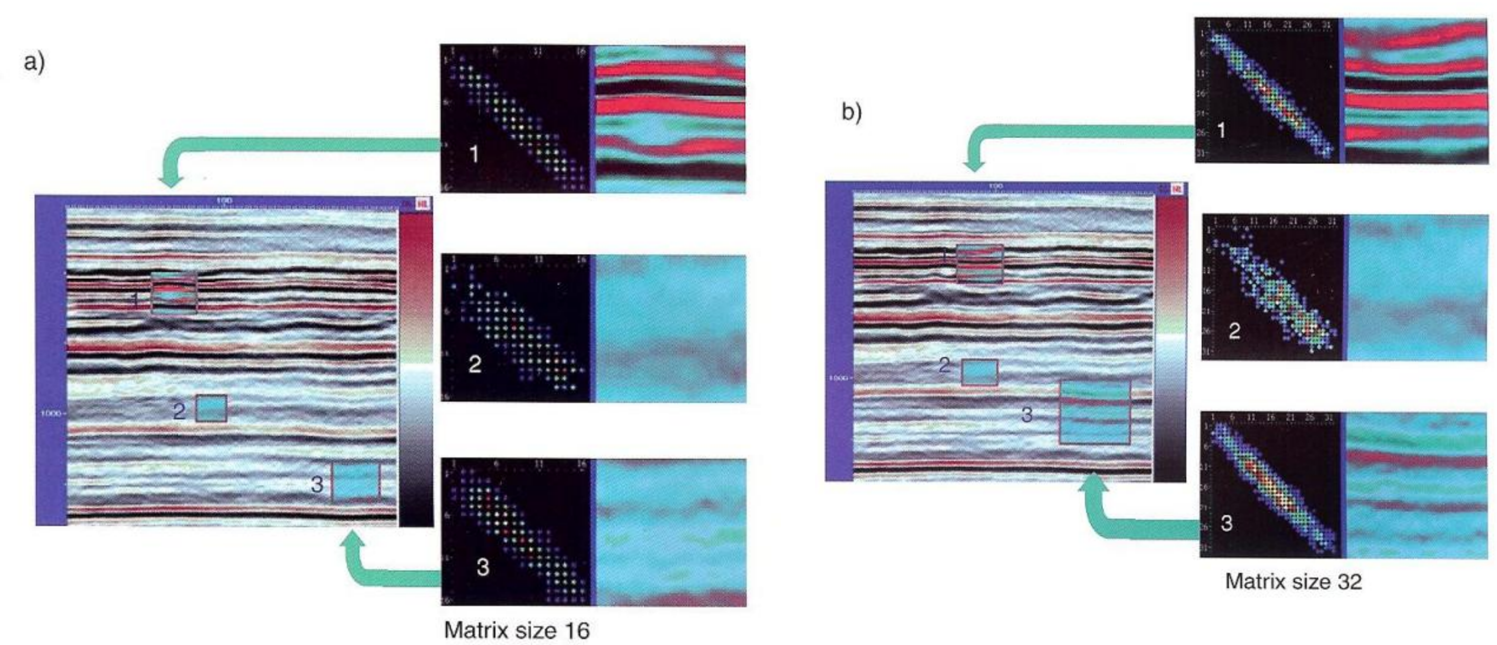
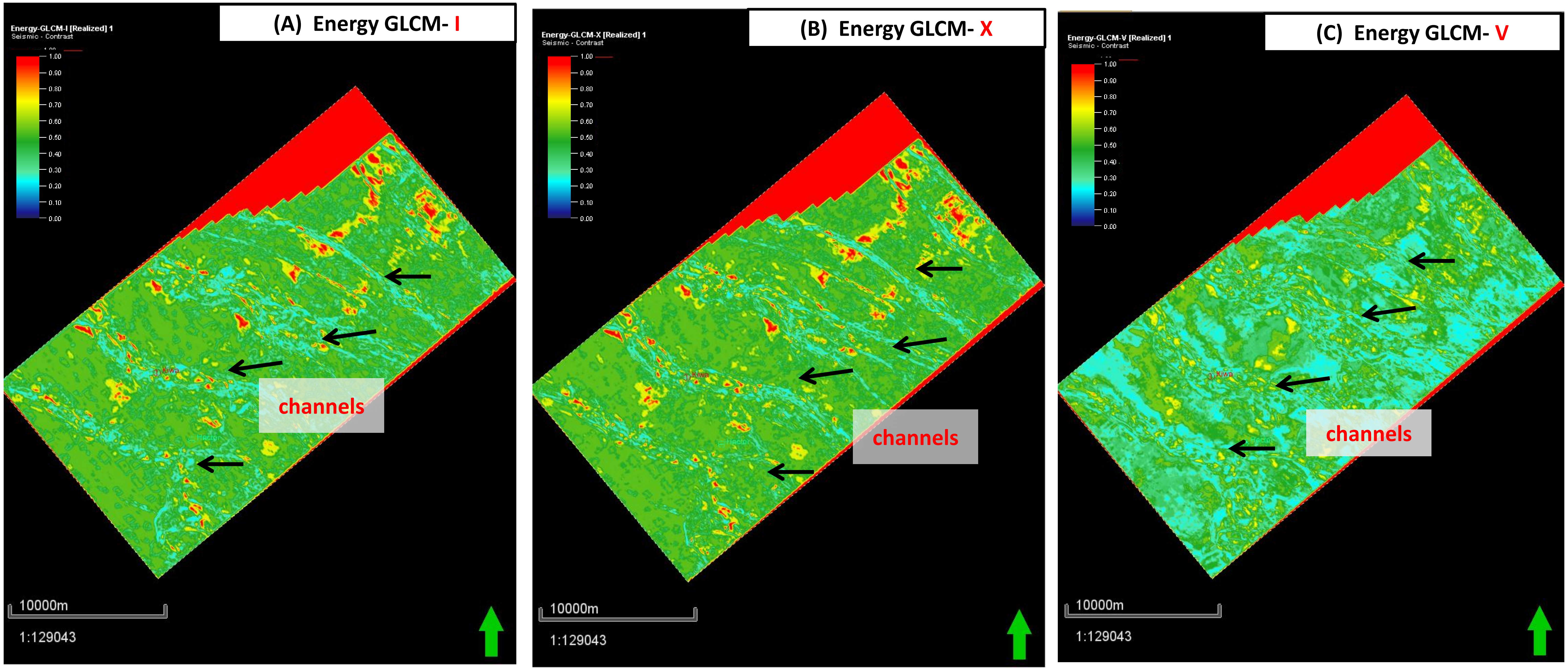


Figure 2: Result of GLCM using by different level; a) 16 by 16 b) 32 by 32 (Chopra and Marafut, 2007)

GLCM (Energy @ 1268)

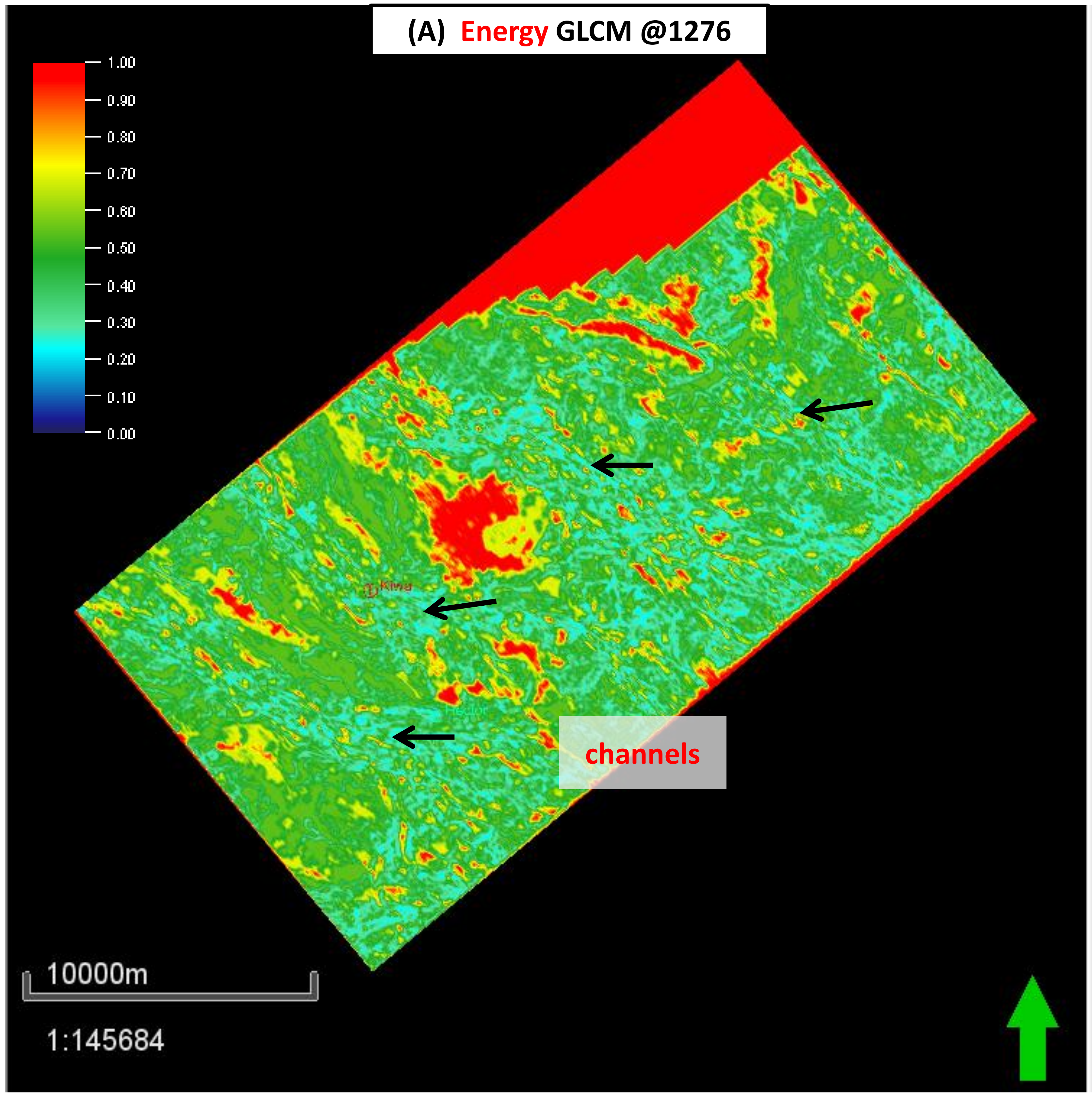


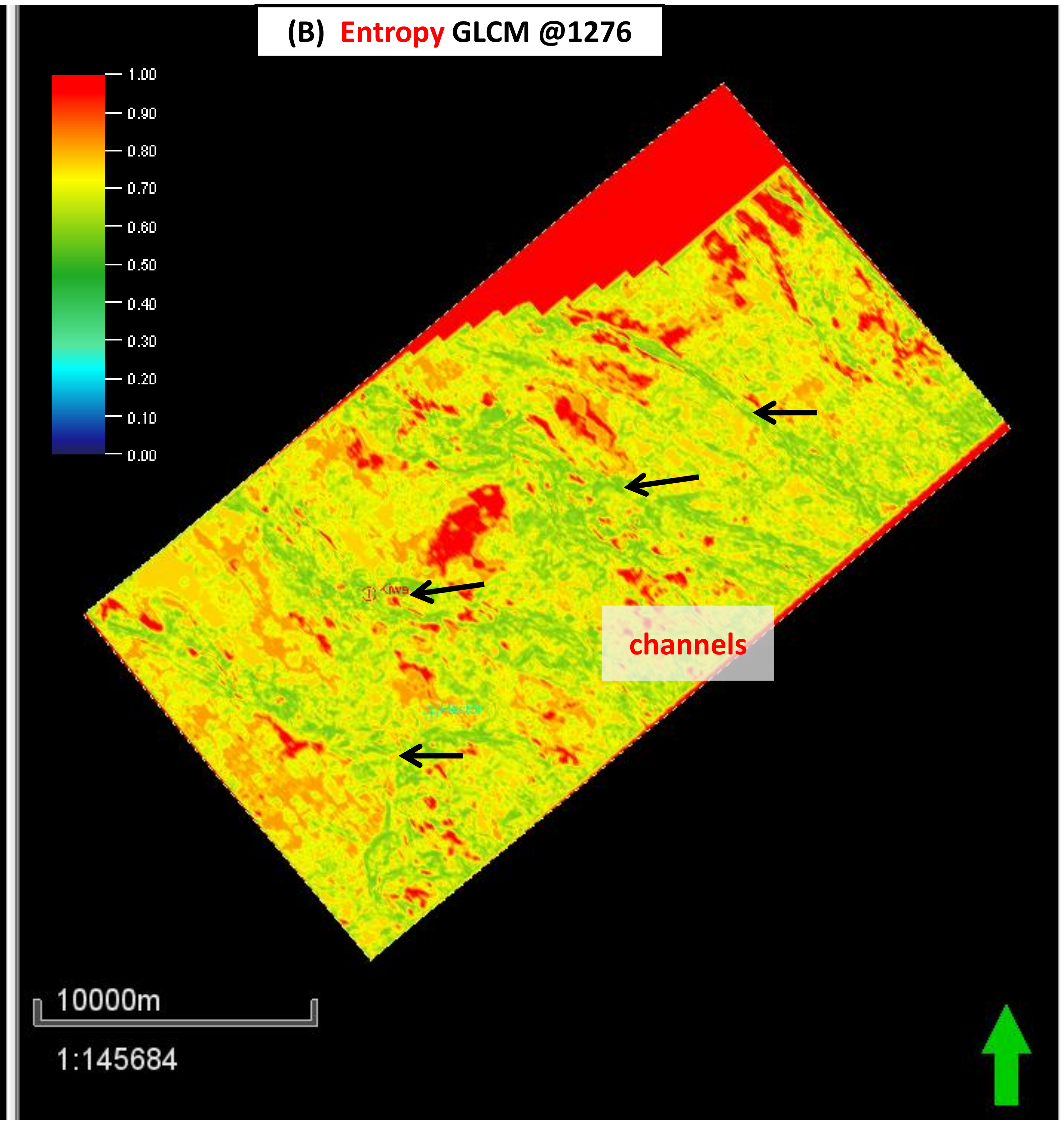
- Here are the results from GLCM attribute using the energy algorithm in sections. Energy algorithm enables the calculation of textural uniformity. Energy is low when all element is GLCM are more uniform, and it is useful for highlighting geometry and continuity (Chopra and Marafut, 2007).
- In the figures, red signifies high level of energy which may also equate to low level of uniformity.
- GLCM operation generates 3 volumes (I, X and V). They represent the primary direction at which the calculations were applied;

    1. volume I=inline direction,
    2. volume x = xline direction,
    3. and volume v = vertical direction.

- Looking at time slices, patterns can be recognized as features related to channels. For volumes I and V, features are not clearly defined; while again for volume X, boundaries of channels can easily be recognized and well defined.

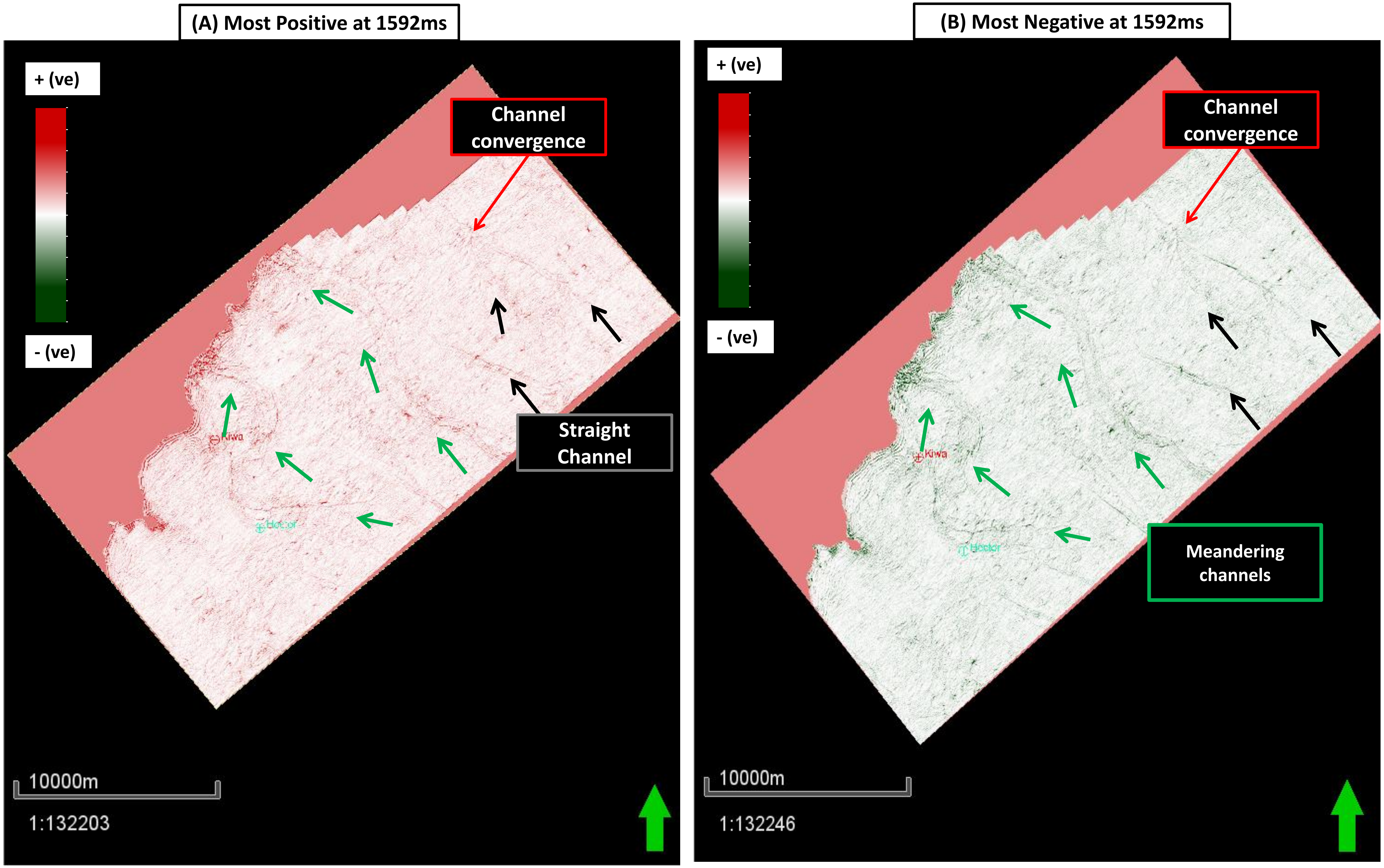
GLCM (Energy and Entropy)





- Here are the results from GLCM attribute using the energy (A) and entropy (B) algorithm in sections. Energy measure the uniformity and entropy measure the disorder of texture.
- Entropy GLCM attributes has provided well defined channel geometry than the Energy GLCM attributes.
- Having relatively low energy low energy, low entropy and high contrast associate with marine shale deposit (Chopra and Marafut, 2007). In time slices, channels show the low energy and relatively low entropy. Thus channels may be filled by marine shale deposit???

Curvature



Here two time slices represent the curvature attributes using default parameters; (B) most positive and (B) most negative.

Both time slices delineate the stratigraphic features (channels), but not very clear. Meandering channels are marked by green arrow and straight channels by black arrow.

Difference between those slice is not observed more obvious on channel features. Most negative give merely clear feature than the most positive curveture.

Sweetness....??

- Sweetness is the implementation of two combined attributes (Envelope and Instantaneous Frequency) and is used for the identification of features where the overall energy signatures change in the seismic data.
- Mathematically, sweetness is derived by dividing reflection strength (also known as ‘‘instantaneous amplitude’’ or ‘‘amplitude envelope’’) by the square root of instantaneous frequency:

  Sweetness=Envelope/SQRT(Inst. Frequency)

- Parts of a seismic volume characterized by both high amplitude sand and low frequency will have high sweetness, where as other combinations of those attributes will have low sweetness.
- High contrast give the strong reflectivity and high sweetness is response to strong reflectivity. Therefore impedance contrast is very crucial when the sweetness attributes is used to distinguish sand from shale.
- Isolated sand bodies in shale successions tend to generate stronger, broader reflections than the surrounding shale and show the high sweetness.
- Sweetness is a seismic can be very effective for channel detection, but becomes less useful when acoustic impedance contrasts between sands and shales are low or when sands and shales are highly inter-bedded.

Petrel help menu & Hart, B., 2008.

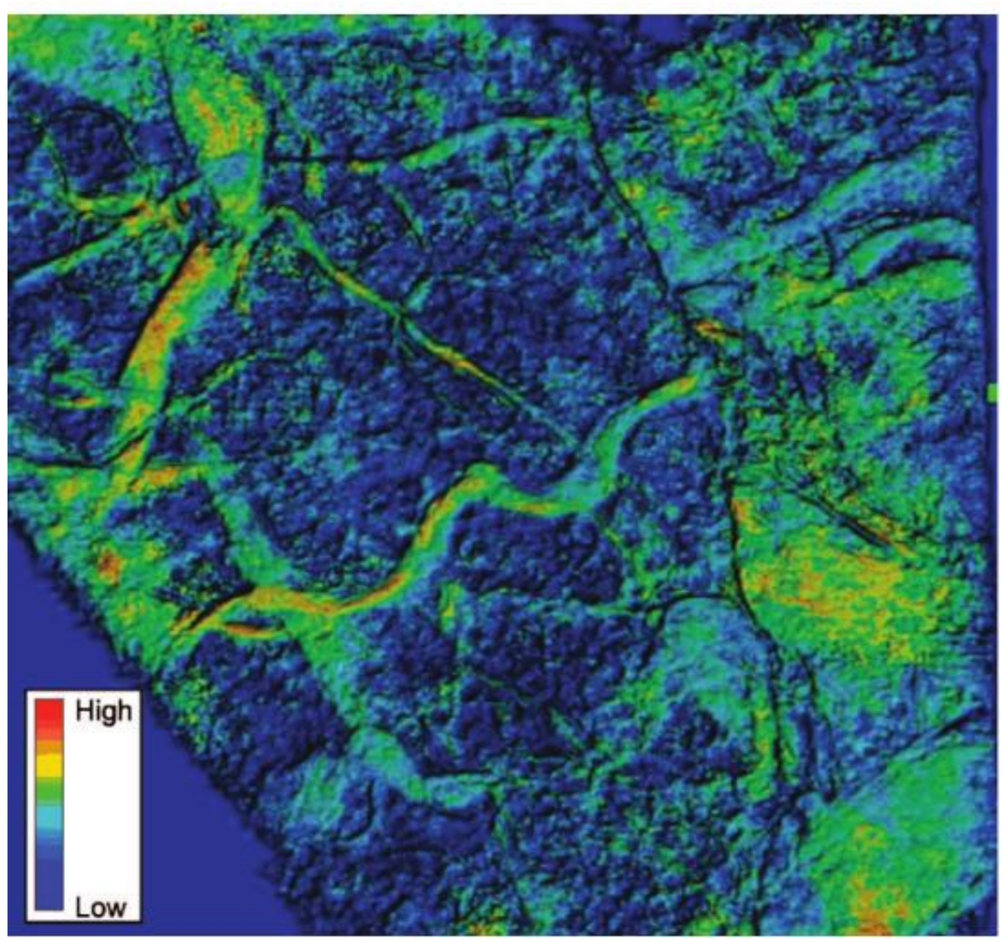


Figure 1: Sweetness to define channel margins and faults, variations in sweetness within channel segments suggest changes in lithology

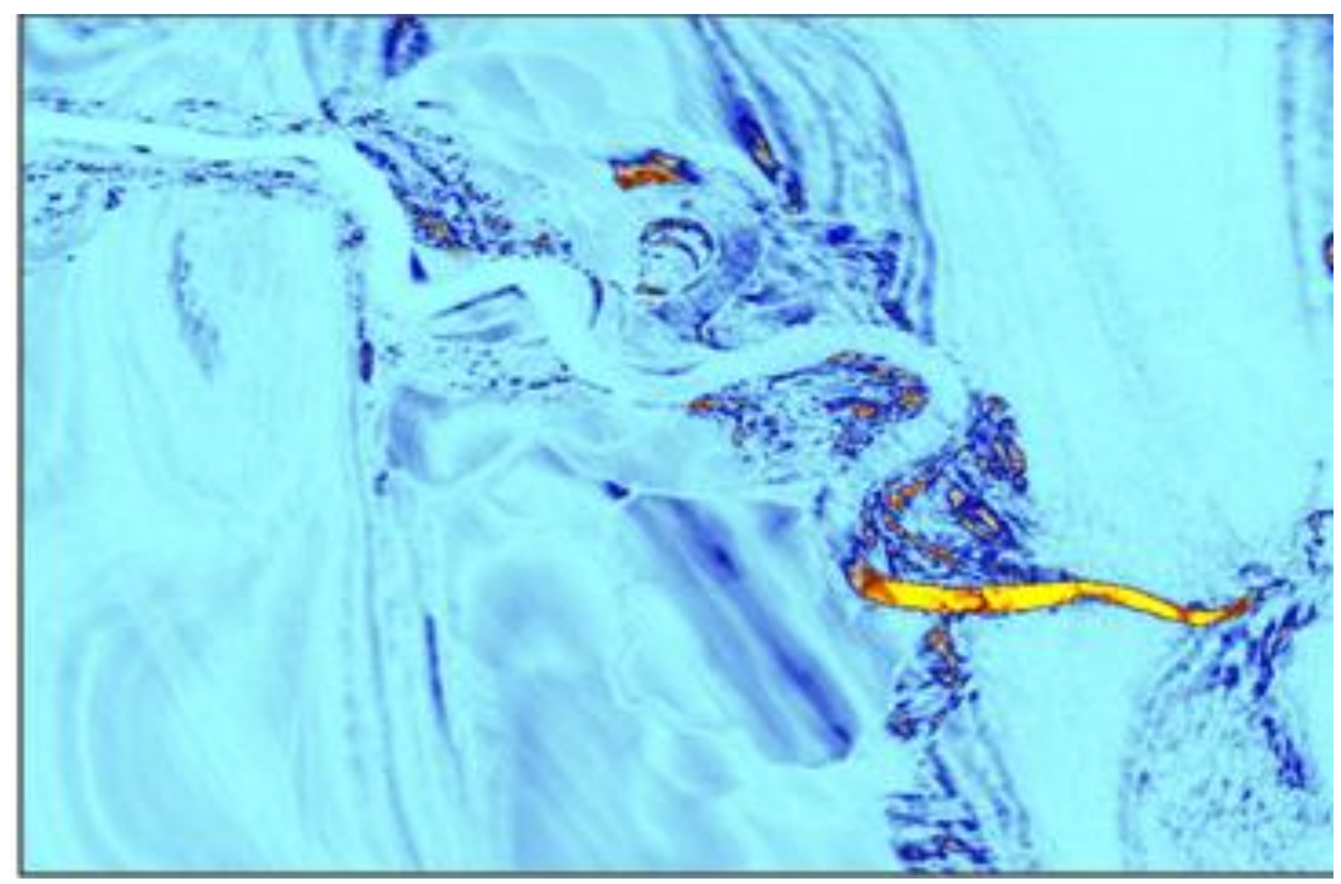
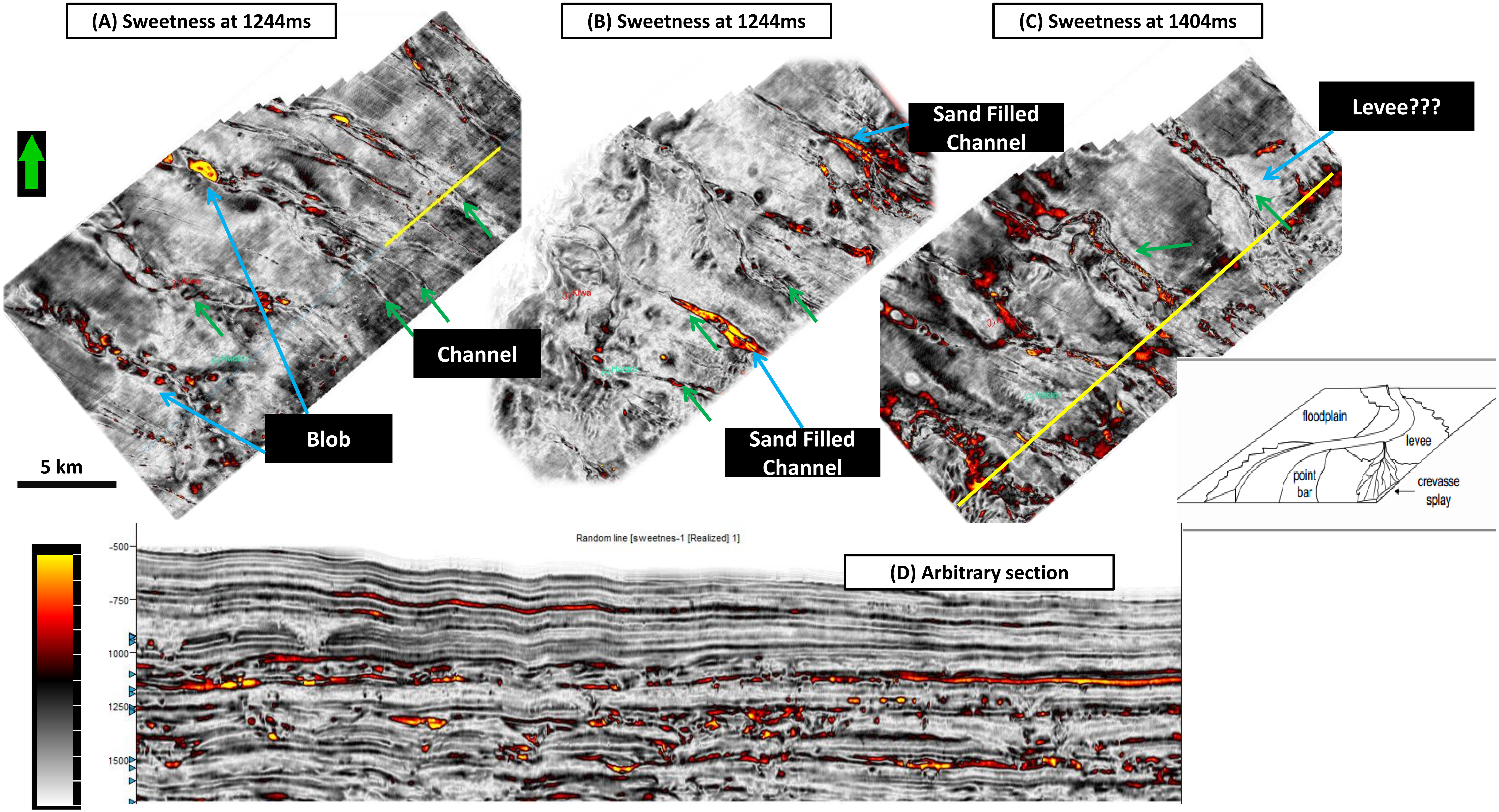


Figure: sweetness to highlight a progressing channel sequence

Sweetness



- Channels boundary are well defined by sweetness attributes in time slices. Some of the channels with high sweetness represents the sand filled channel (Fig. B)??
- Some of the high sweetness blobs are observed within channels and two sides of the channels. They may indicate sand bodies/ Presence of hydrocarbon/ high porosity regions.
- Arbitrary vertical line shows sand bodies are not continuous vertically and laterally (Fig. D)??
- This indications are not absolute and should always be cross -checked with other data sources. Because different factors can effects the sweetness (such as pore-filling fluids, Tuning effects, impedance contrast etc.)

Iso-frequency

- The Iso-Frequency Component generates a volume attribute through a patented seismic decomposition method for user-defined frequencies (Pepper and van Bemmel, 2001)
- The contribution of individual frequencies to the make-up of the input seismic signal. Useful for isolating frequency-dependent changes in the signal, such as stratigraphic thinning and fluid effects. The output volume is the local contribution of the selected frequency at each sample position.

- Parameters of this process:
    1. Desired frequency (Hertz)
    2. Number of cycles
- The desired frequency is the isolated frequency component to extract from the input seismic volume.

- "Number of cycles"; this option defines the length of the analysis window to extract the contribution of the selected frequency is determined by this parameter. The analysis window length will be longer for lower frequencies and shorter for higher frequencies for a defined number of cycles.

- Short windows will not focus the correlation energy to illuminate anomalies, while too long windows will show local geologic effects and not tuning effects.

Petrel help menu & Azevedo and Pereira, 2009.

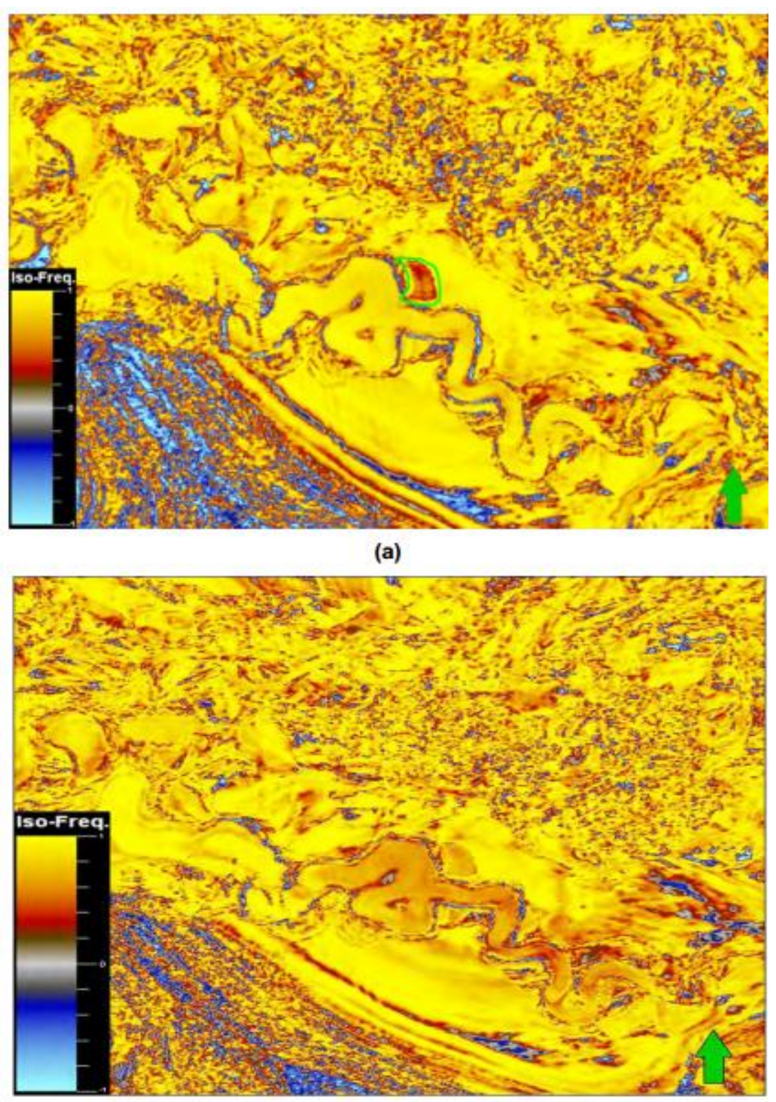
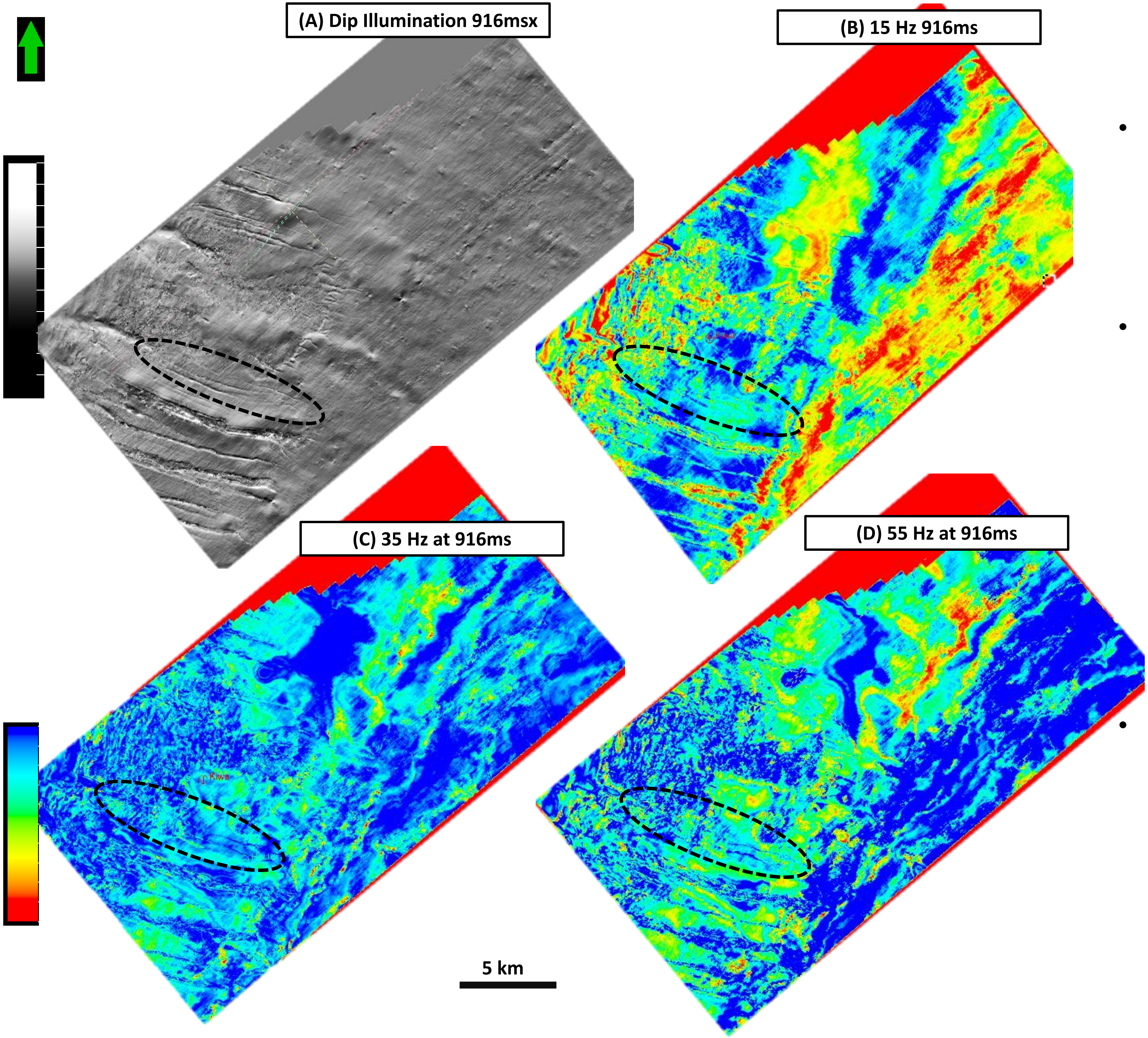


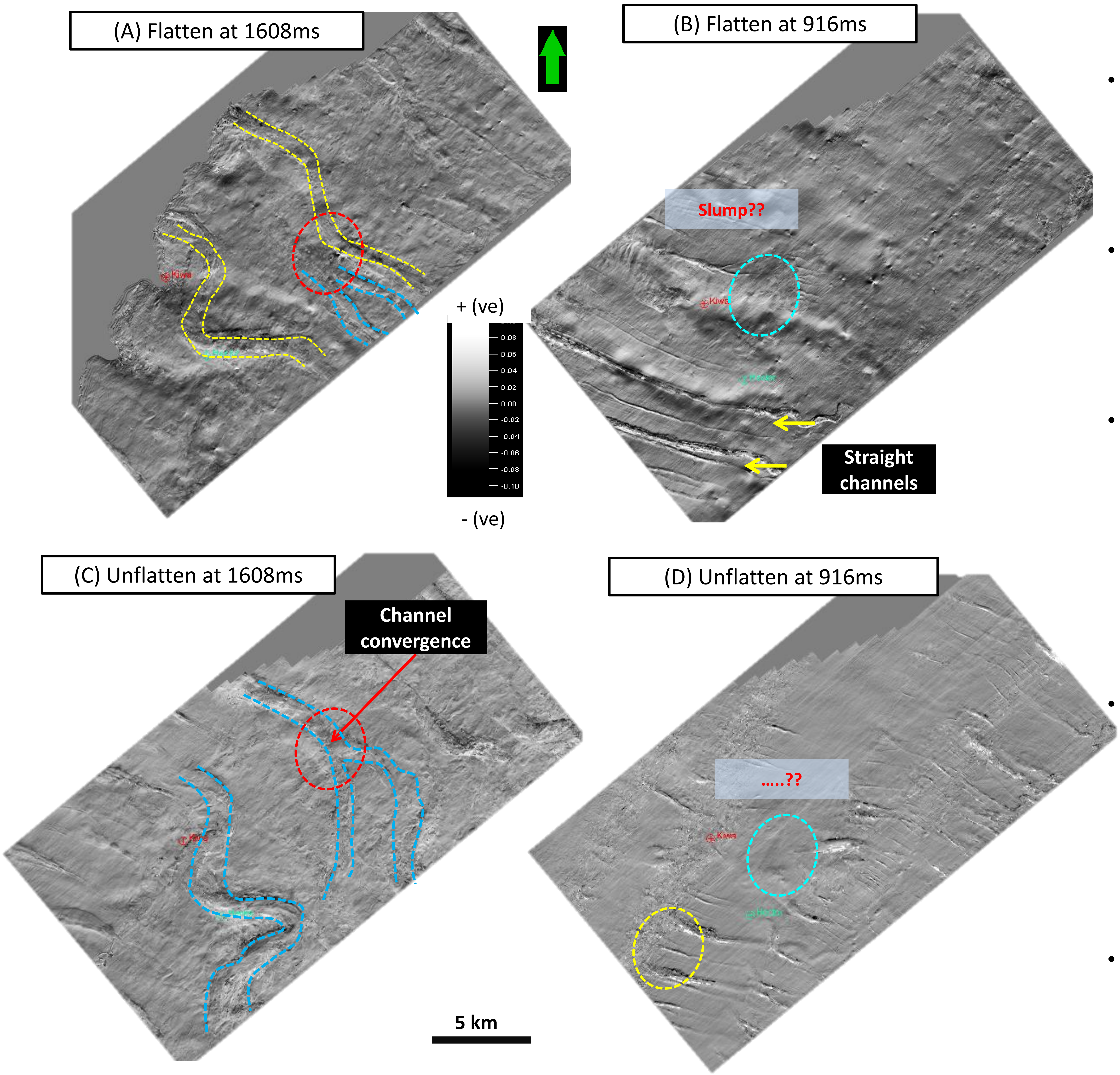
Figure 77 – Same time slice position for two Iso-Frequency volumes computed with a cosine wave of (a) 25 Hz and (b) 45 Hz. When (a) and (b) are compared, it is clear that inside the meandering channel there are different values for the correlation, which may indicate changes in lithology inside it.

Iso-frequency



- Here time slice maps B, C and D represent the iso-frequency map for 15, 35 and 55 Hz at 916 ms.
- In low frequency 15Hz marked area doesn't show any channel. But in high frequency 35 and 55 Hz has provided the channel feature. In addition, this channel in 55 Hz frequency has relatively well defined than the iso-frequency in 35 Hz.
- 15 Hz slice is not capable to delineate the channel in marked zone, this may be because of the channel is not thick enough to tune.

Original cropped volume vs Flatten cropped volume (Dip Illumination)



- Dip illumination at 45 degree direction has showed the best stratigraphic features (Channels) compare to other attributes in this study.
- Here four time slice of dip illumination are presented to compare the results of attributes between flat (A,B) and unflatten volume (C,D).
- Time slice at 1608ms in flat volume two separate meandering channel and they doesn't shows any convergent point (A). But at inflated volume slice shows NE meandering channel converge with another channel (red circle) and SW channel provided in different geometry (C).
- Again, time slice at 916ms in flat model, it is clearly observe the slump sediments feature, feeder channels and continuous straight channels. But in unflatten, it doesn't gives any slump features and a segment of the continuous straight channels (yellow circle).
- To sum up, The flattened model enables us to see the model as it was when the layers were originally deposited.

Summery

- In this exercise, all of the attributes extraction process are run for the cropped flatten volume. Among those attributes dip illumination for 45 degree direction provided the well defined stratigraphic features (channels).
- The dip illumination attributes also run for unflatten volume with same parameter. Compare to these results flatten attunes gave more consistence and reliable feature. On the other hand, unflatten volume showed wrong and incomplete features.
- Again, in dip illumination 45 degree view is comparatively more clear than the 135 degree view.
- For consistent dip attributes Inline dip has provided more clear features than Crossline dip.
- In GLCM, Energy algorithm enables the calculation of textural uniformity and entropy measure the disorder of texture. Within the three output Iand V, features are not clearly defined; while again for volume X, boundaries of channels can easily be recognized and well defined. Besides, Entropy GLCM attributes gave better features geometry than the Energy GLCM attributes.
- Sweetness is a seismic can be very effective for channel detection and differentiate the sand bodies. Some of the channels with high sweetness may indicate sand bodies/ Presence of hydrocarbon/ high porosity regions. This indications are not absolute and should always be cross -checked with other data sources.
- Iso-frequency map helps to determine the deposition and/or extension of the channel and identify the tin bed tuning.
- To sum up, applying different types of attributes in seismic volume is to get better and reliable idea about depositional environment and structural and stratigraphic features.