PS Seismic Attribute Mapping in Carbonate Depositional Environment, Some Lessons from Case Studies*

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Abstract

2-D/3-D seismic attribute mapping is a widely used tool to extract geo-morphological, structural, stratigraphic and reservoir properties information from seismic data. These geometric, kinematic, dynamic and statistical measures allow revealing a better qualitative (sometimes quantitative) interpretation. One of the advantages of this approach is to illustrate subtle features, which shows no evidence on conventional seismic images.

However, it is difficult to choose the ‘right attributes’ in specifically carbonate depositional environments, from a pool of seismic attributes stemmed from different mathematic algorithms. Here we present some case studies, which show that by using seismic attribute mapping, the evolution of lateral extension of carbonate buildup complexes in 3-D can be reconstructed. What's more, some subtle features are illustrated when the ‘right attributes’ are chosen, such as the organization of karstification and of subtle shoal build up. Based on these cases studies, a seismic attributes ranking for the carbonate depositional environment is proposed in order to establish a list of a prior attributes to be computed at the exploration stage.

Concerning to our observations, different attributes are easily associated to some specific geological objects. For example, karstification is more visible on coherency maps. Clinoform and progradations are visible for time slices or horizon slices. Subtle shoal buildups can be highlighted by a neural classification method and reflector convergence (3-D process of dip integration attribute applied on each seismic trace in order to highlight stratigraphic limits). Low frequency components in spectral decomposition can provide some coherent noise out of the zone of interest while the main frequency does not.

The reliability of the seismic attribute is also based on the quality of seismic data. When dealing with noisy data and hunting for a laterally subtle facies change, a reconditioning processing (for example anti-noise and/or dip-driven filter) should be done for the dataset first to have meaningful attribute maps.

In conclusion, by investigating the texture of the seismic data from selected volumetric, surface and interval seismic attributes, the geomorphology, stratigraphic information and reservoir properties can be revealed and illustrated in carbonate depositional environment, taking into account of course the limitations of seismic resolution and data quality.

Seismic Attribute Mapping in Carbonate Depositional Environment, some lessons from case studies

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Introduction

2D/3D seismic attribute mapping is a widely-used tool to extract geo-morphological, structural, stratigraphical and reservoir properties information from seismic data (Figure 1). These geometric, kinematic, dynamic and statistical measures allow revealing a better qualitative (sometimes quantitative) interpretation. One of the advantages of this approach is to illustrate subtle features, which show no evidence on conventional seismic images (Figure 2).

Case studies

However, it is difficult to choose 'the right attributes' in specifically carbonate depositional environment, from a pool of seismic attributes stemmed from different mathematic algorithms. Here we present some case studies, which show that by using seismic attribute mapping, the evolution of lateral extension of carbonate buildup complexes in 3D can be reconstructed. What's more, some subtle features are illustrated when the 'right attributes' are chosen, such as the organization of karstification and of subtle shoal-type buildups. Based on these case studies, a seismic attributes ranking for the carbonate depositional environment is proposed in order to establish a list of a prior attributes to be computed at the exploration stage.

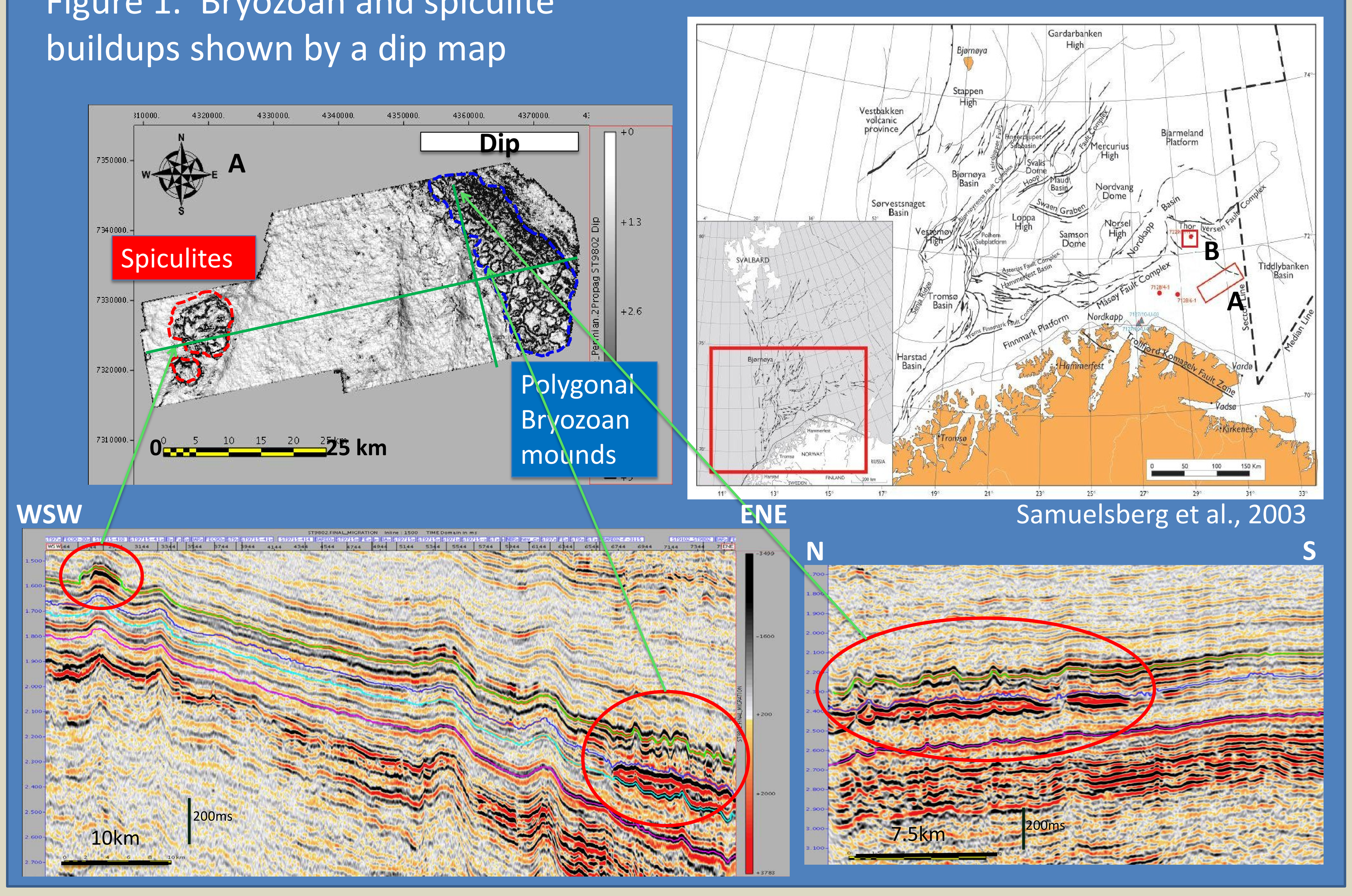


Figure 1. Bryozoan and spiculite buildups shown by a dip map

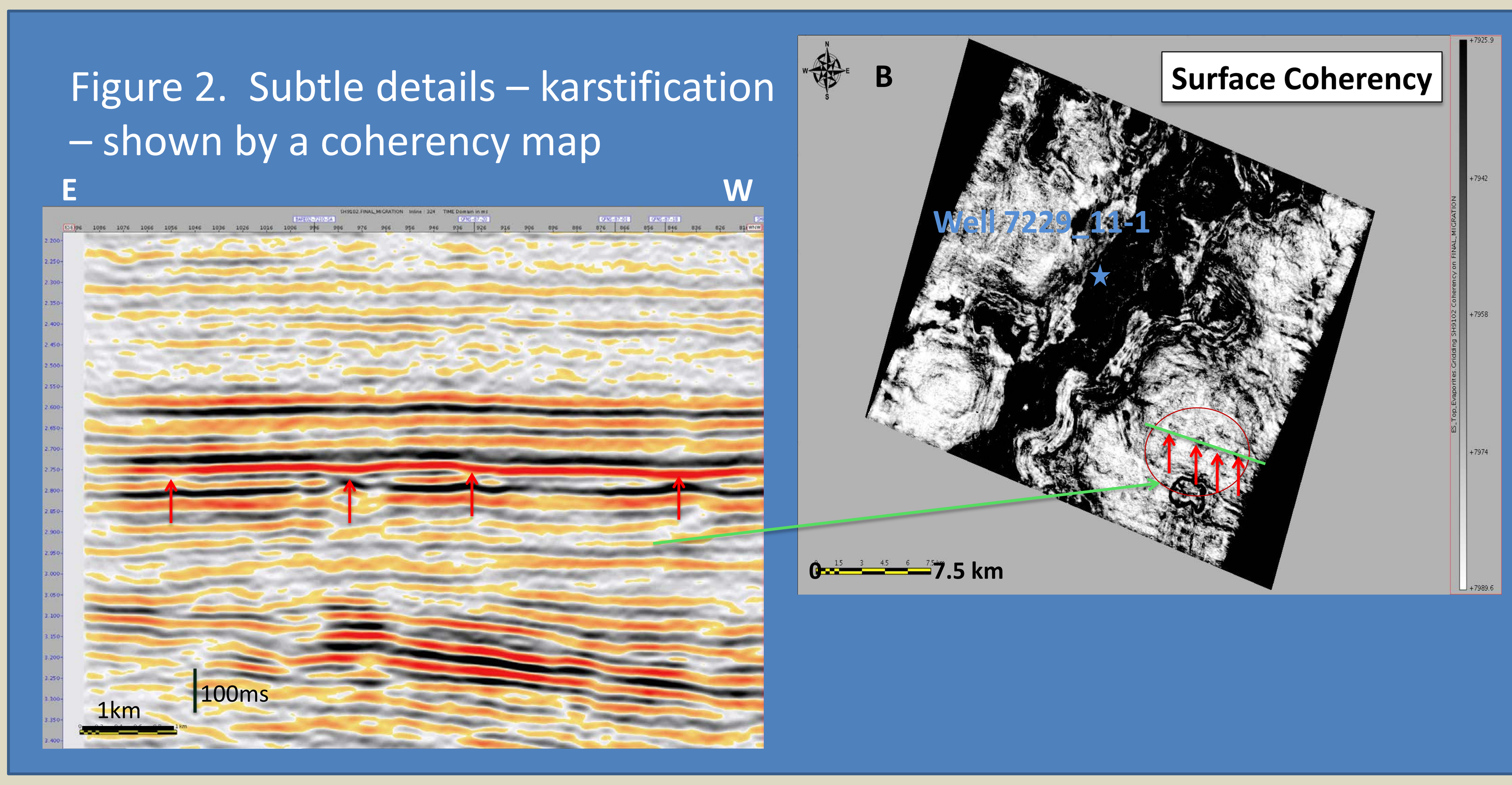


Figure 2. Subtle details – karstification – shown by a coherency map

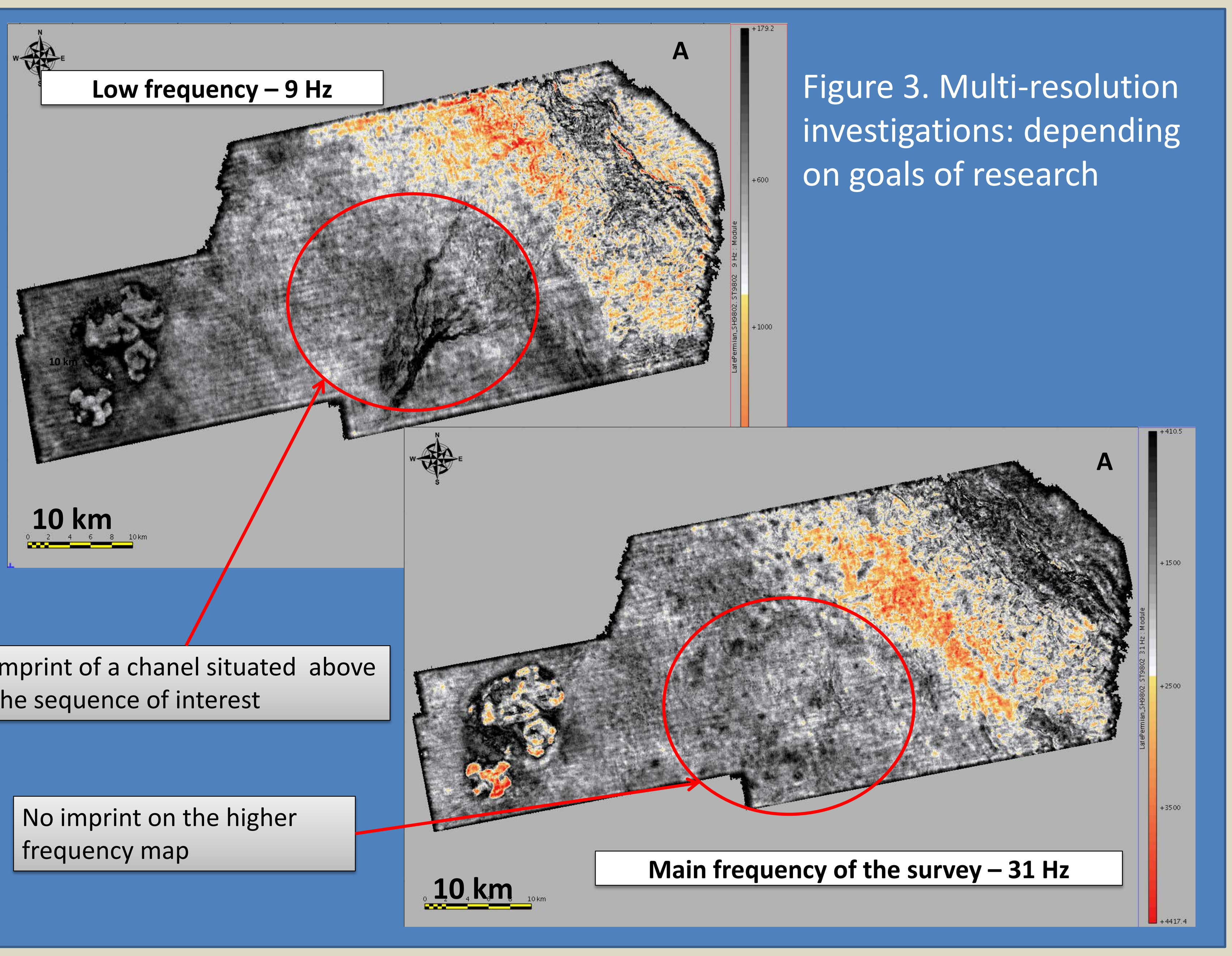


Figure 3. Multi-resolution investigations: depending on goals of research

Concerning to our observations, different attributes are easily associated to some specific geological objects. For example, karstification is more visible on coherency maps (Figure 2). Clinoforms and progradations are visible on time slices or horizon slices (Figure 4). Subtle shoal buildups can be highlighted by a neural classification method and reflector convergence (3D process of dip integration attribute applied on each seismic trace in order to highlight stratigraphical limits) (Figure 5). Low frequency component in spectral decomposition can provide some coherent noise out of the zone of interest while the main frequency does not (Figure 3).

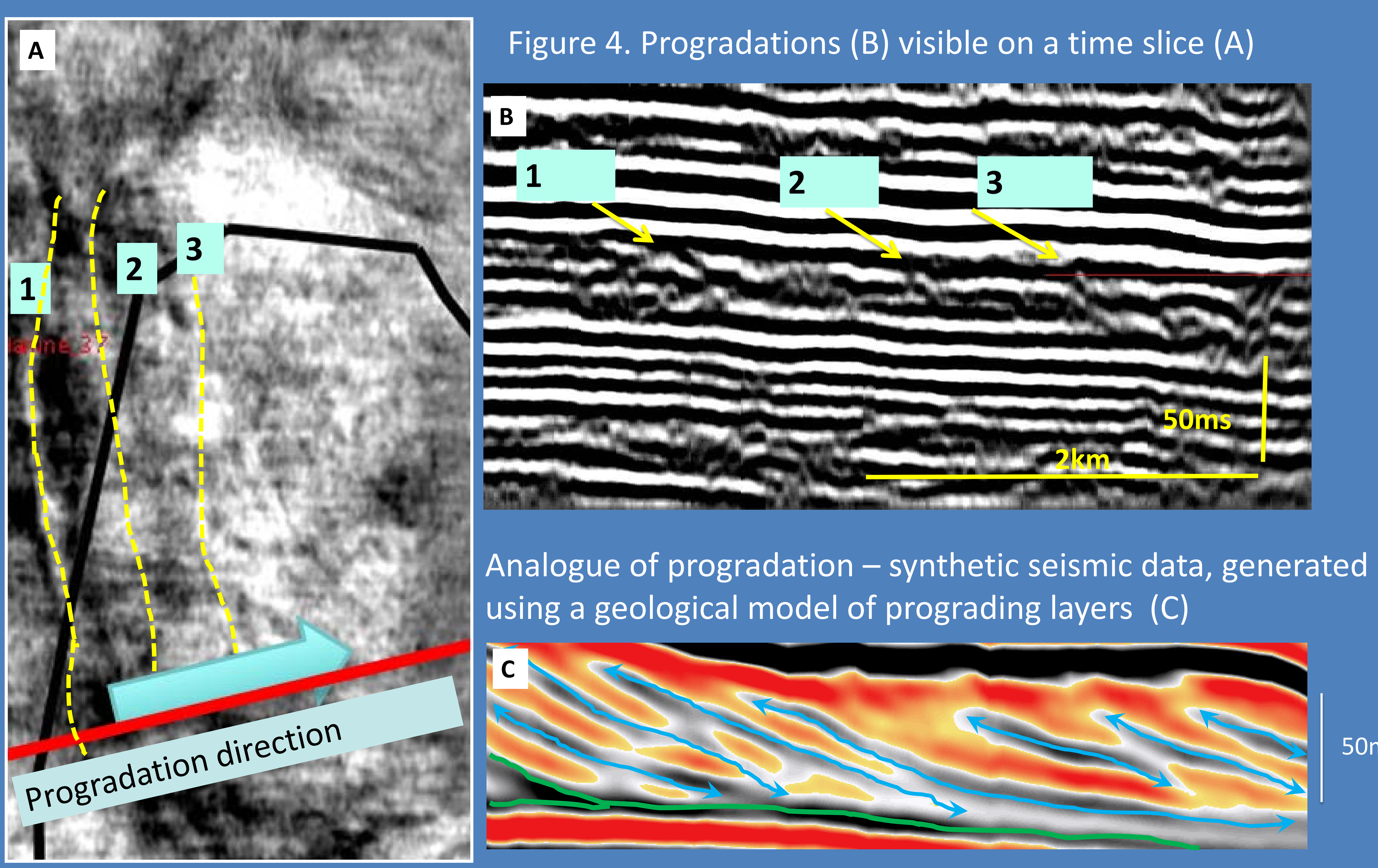


Figure 4. Progradations (B) visible on a time slice (A)

Analogue of progradation – synthetic seismic data, generated using a geological model of prograding layers (C)

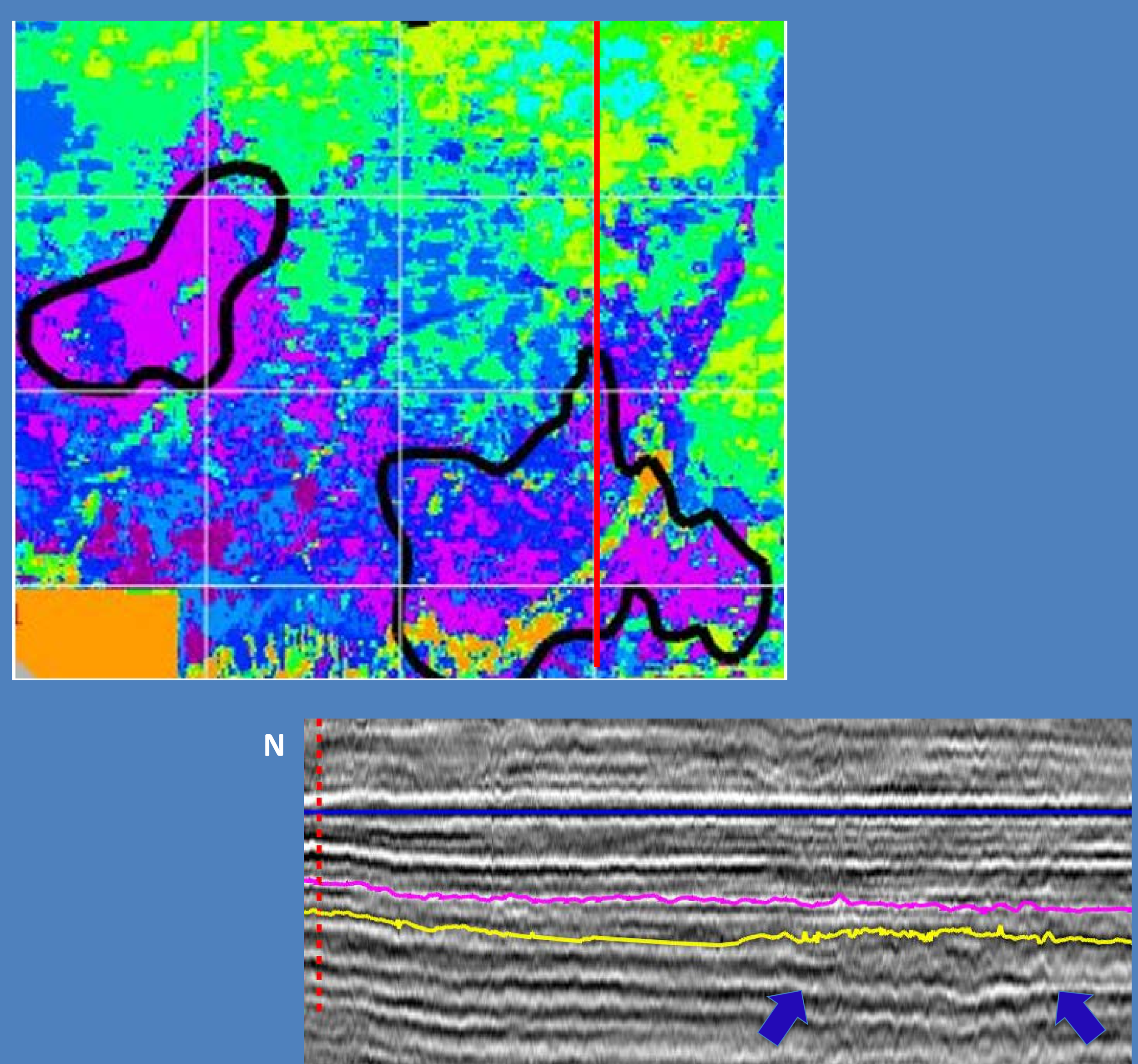


Figure 5. Subtle shoal buildups highlighted by a neural classification method

Multi-attribute analysis

Multi-attribute analysis is one of the future techniques to alleviate the problems interpreters face because of an overwhelming number of attributes (Chopra and Marfurt, 2006). Some diverse works are published in order to help the reservoir characterization in clastic deposition systems (Clawson et al., 2003; Rahimi, 2012; Rezvandehy et al., 2011; Saggaf et al., 2003; Steeghs et al., 2000). Here are shown some case studies and lessons learned from our recent multi-attribute mapping results in complex and heterogeneous carbonate depositional systems, Middle East (Figures 7-8).

Figure 6. Workflow used in interpretation based on multi-attribute analysis

Single Seismic Attributes Calculation → Extraction and Selection of Meaningful Independent Seismic Attributes → Combined Seismic Attributes Volumes (← Classification Techniques) → Interpreted Volume (← Wavefield Modeling)

Workflow

Our workflow (Figure 6) consists of, firstly, extracting the single independent seismic attribute mini-cubes, then generate a learning set from selected mini-cubes by a classification tool, such as neural classification. In the first step, some geological information is already identified and highlighted as can be seen on the examples shown above (Figures 1-5). The second step is essential for subtle stratigraphical features like channel systems and incised valleys (Figure 7), shoal-type mounds or low-angle progradation units (Figure 8), which are not obvious in conventional attribute mapping. In this step, the ambiguity of interpretation is significantly reduced thanks to selective criteria according to each object: morphology, frequency or seismic internal facies. With help of other available geological data, a geological and then seismic model can be constructed in order to confirm the initial interpretation (Figure 4C). This last step is iterative since the seismic modeling can rarely match perfectly with the real seismic data.

Figure 7. Amplitude + Instantaneous phase + Instantaneous frequency

Channel systems or incised valleys

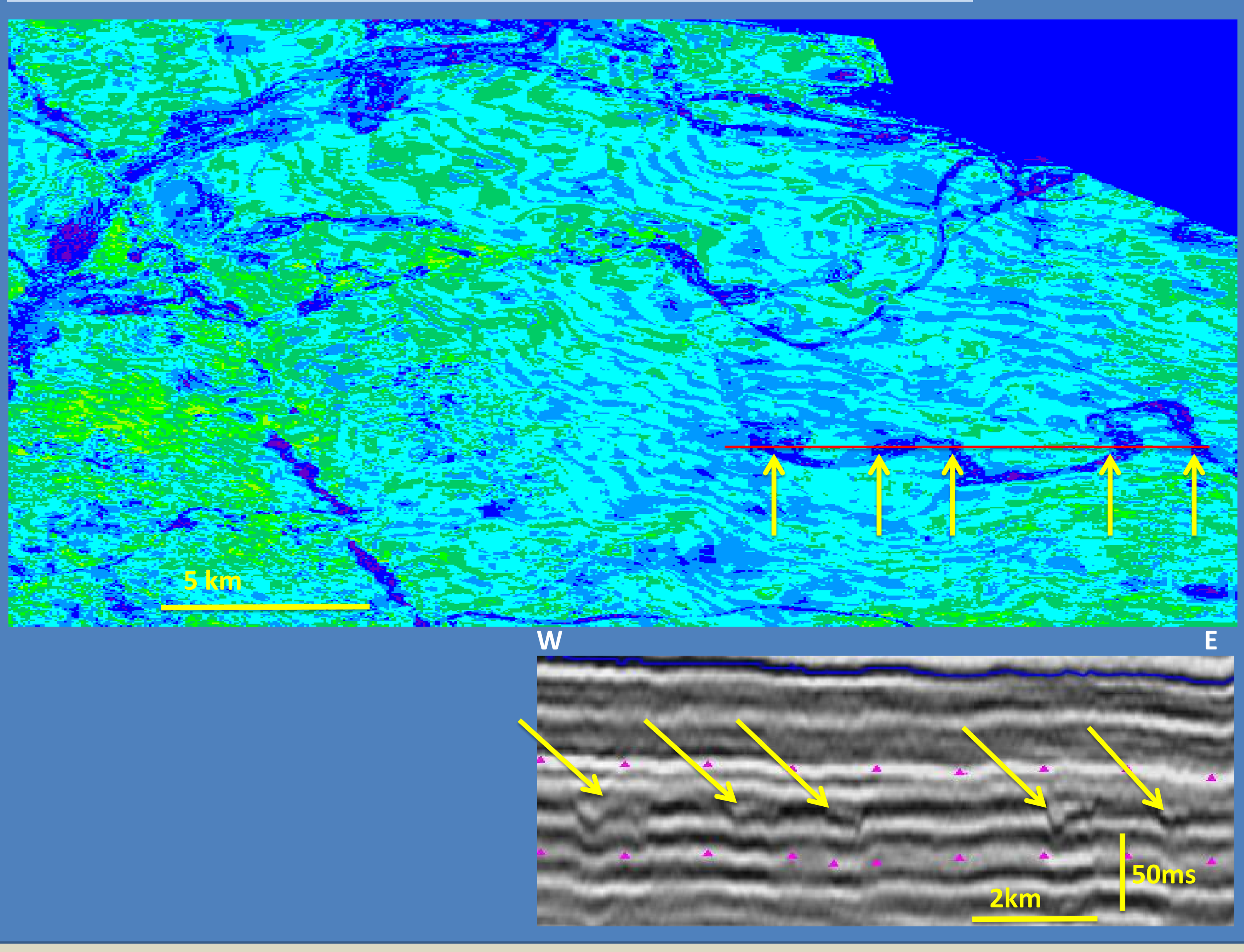
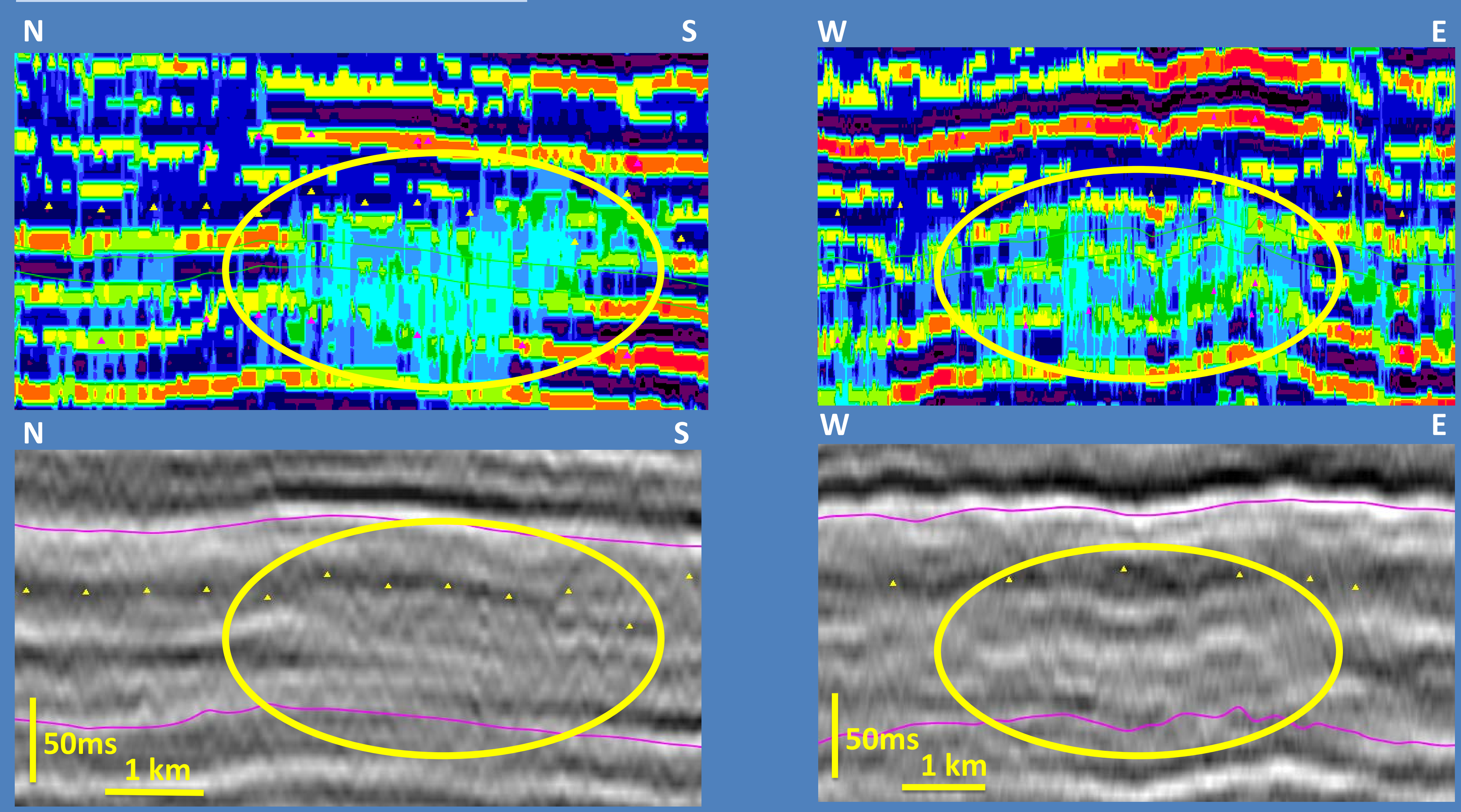
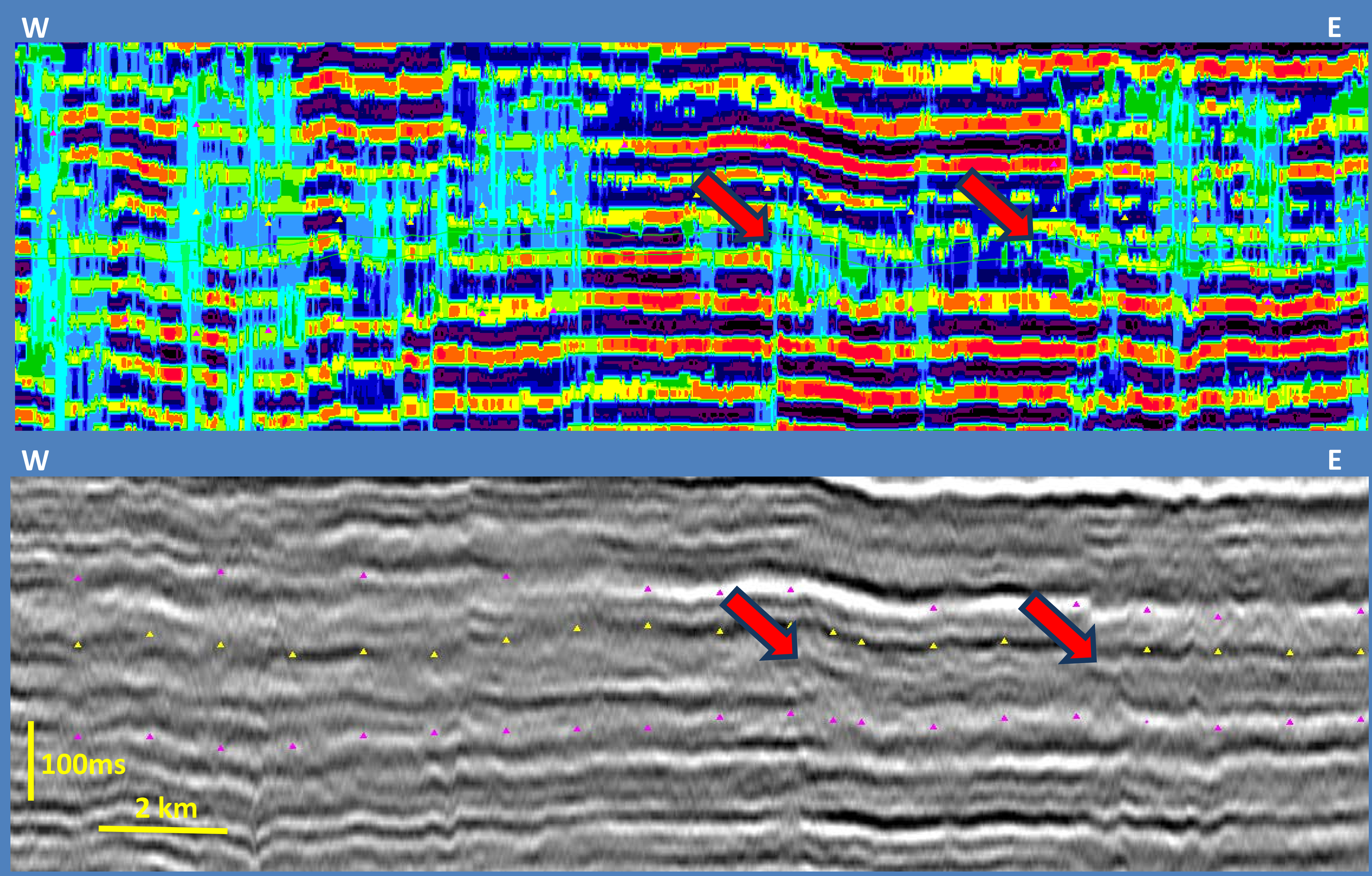


Figure 8. Autocorrelation + Chaotism + Coherency + Dominant frequency

A – Shoal-type mounds



B – Low-angle progradation units

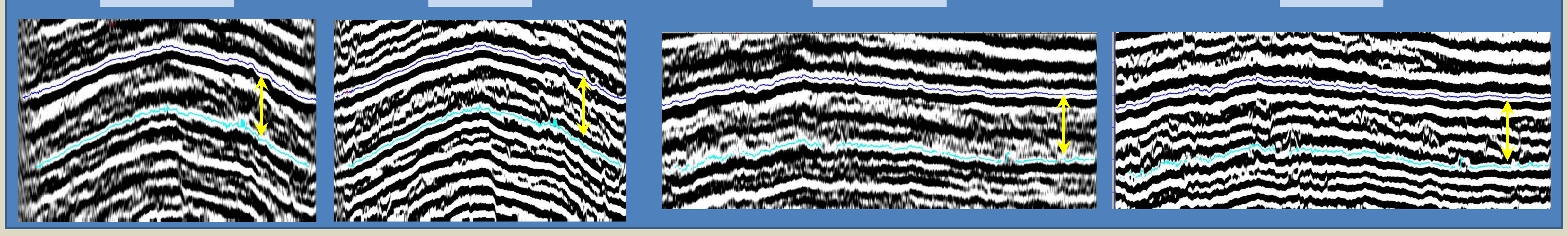


Pre-conditioning processing

When dealing with noisy data and hunting for a laterally subtle facies change, a pre-conditioning processing (for example anti-noise and/or dip-driven filter) should be done for the dataset firstly to have meaningful attribute maps (Figure 9).

Figure 9. Pre-conditioning processing impact on seismic data

Before After Before After



Conclusions

The limitations of seismic resolution and data quality are essential to the quality of seismic attribute mapping. By investigating the texture of the seismic data from selected volumetric, surface and interval seismic attributes, the geomorphology, stratigraphic information and reservoir properties can be revealed and illustrated in carbonate depositional environment, taking into account, of course, the limitations of seismic resolution and data quality.

For carbonate environments, due to its combined effect of variation in depositional facies and diagenetic alterations, it is not always adequate to follow a standard interpretation routine and more sophisticated techniques are demanded.