

Thin-Layer Reservoir Prediction Method of Rifted Basin Based on Low-Resolution Seismic Data*

Ke Weili¹, Zhang Guangya¹, Yu Yongjun², Liu Aixiang¹, Yang Cang², and Huang Tongfei¹

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Abstract

Limited by the unfavorable ground surface conditions over Fula Sub-Basin, Muglad Basin that developed along with Central African Rift Zone, only low-resolution 3D and 2D seismic data could be acquired. Using traditional reservoir prediction methods will encounter great difficulties on identifying thin layers, generating accurate well-seismic ties and identifying clear and reliable sedimentary phenomenon for hidden hydrocarbon reservoirs. The dominant frequency of the target reservoir is about 20 Hz, the thickness is 3 to 5 meters, and the sedimentary facies changes from delta sheet sand to alluvial sandstone or mouth bar in delta plain. In order to resolve these problems, the research team tried to find effective technical methods from the several aspects as seismic inversion work, detailed sequence stratigraphy study and seismic sedimentology analysis.

For the seismic inversion work, the new method named by waveform BP-ANN inversion based on spectrum subdivision and analysis was used. With this new idea, firstly, the spectrum subdivision using wavelet transform was carried out on the pure wave seismic data and then generated separate data with effective high, middle and low levels of frequency, among which higher frequency reflects thin layers and low frequency reflects regional trends of lithology changes. Then, sensitive analysis on effective sandstone reservoir was done, and several sensitive attributes of well logging parameters were selected to attend the inversion. After that, a specified BP-ANN was trained to get a stable prediction network between well logging's sensitive parameters and seismic data's waveform, which was then used to carry out hydrocarbon sandstone classification on seismic data in the target formations. With this method, well logging sample's interval can greatly improve the resolution of inversion result. Thin layers of sandstone with thickness less than 10 meters, mostly delta sheet sandstones, could be identified accurately.

Also, detailed sequence stratigraphy study was carried out in the forth-level sequence cycles, which is controlled by the local flood surface, sudden water transgression and sand accumulation. Regarding well core sample analysis and frequency analysis on sequence cycles, well correlation and seismic sequence cycles were used to identify sequence cycle boundaries in both depth and seismic domains and built regional sequence frameworks. Based on the sequence cycle analysis and seismic sedimentology theory, time slices were generated on the seismic

inversion result data with a reasonable time interval. Finally, we developed reasonable micro-facies maps for each sequence cycle using the dominate micro-facies for each cycle, as well as sand thickness distribution and porosity distribution maps.

After reviewing the previous recent study in the research area, it revealed that the hydrocarbon reservoir, in most cases, was sealed by faults horizontally. 3D interpretation, time slice and structure filter process were then done to improve the accuracy of faults identification. Combined with the above three achievements, we identified several favorable targets for drilling and received great success. After years of practice, the method used in this research has been proved a very reasonable way for successful exploration activities in mature rifted sedimentary basins with low-resolution seismic covering.

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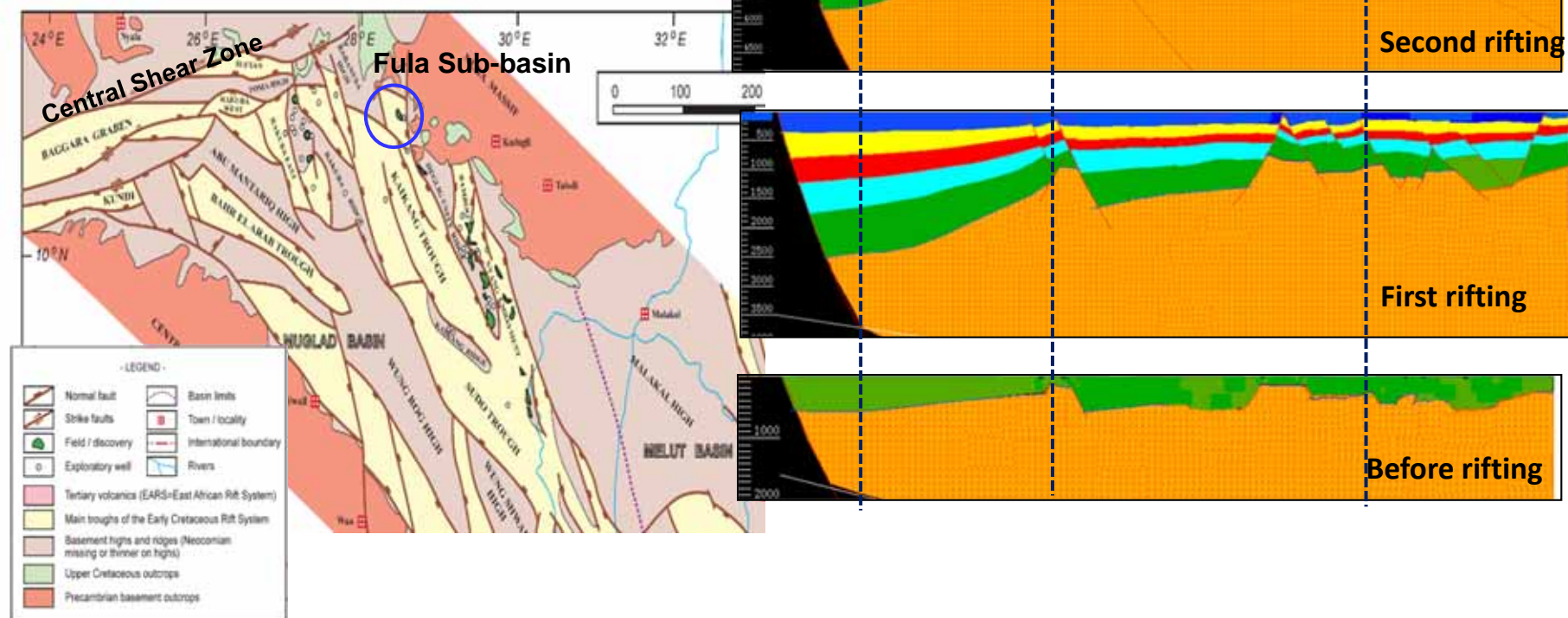
1. General
2. Method&Solution
3. Case Study
4. Discussion

General

1. Regional Geological Background

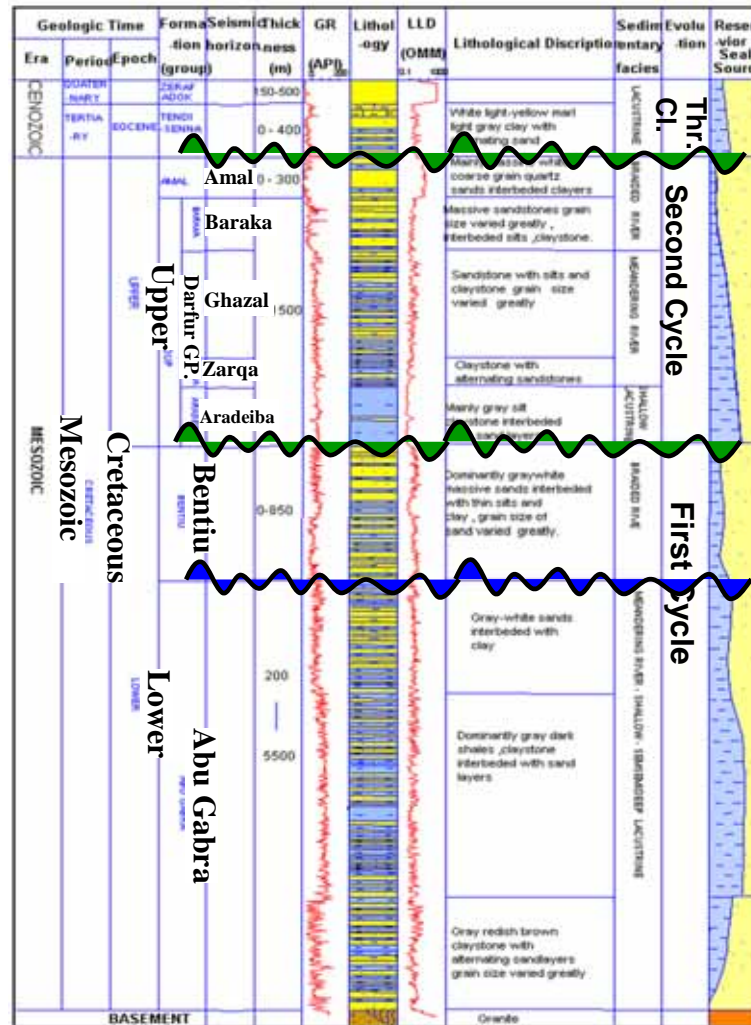
- Muglad basin is one of the Cretaceous-Tertiary rifts basins along with the Central African Shear Zone (CASZ)
- Fula sub-basin is in the north area with area of 3300 km²

Structure Schema of Muglad Basin (IHS, 2009)

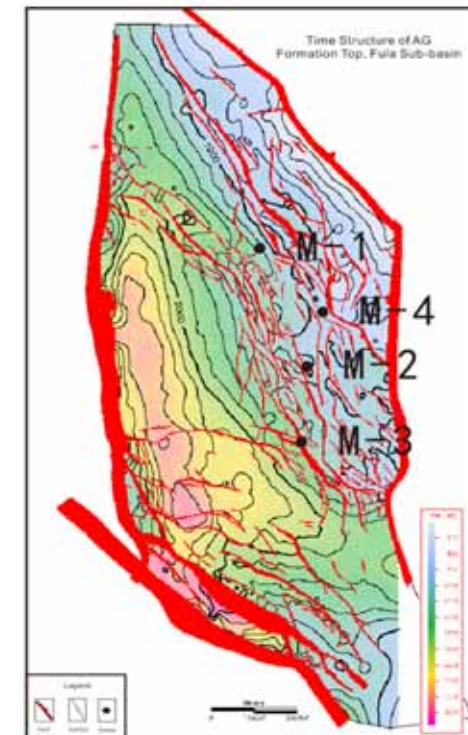
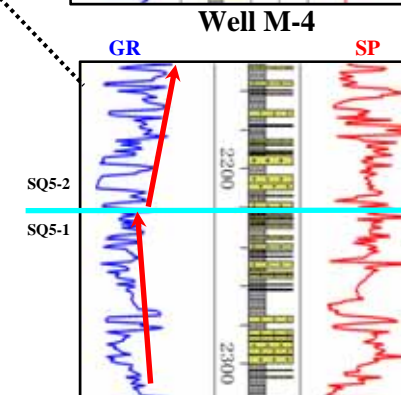
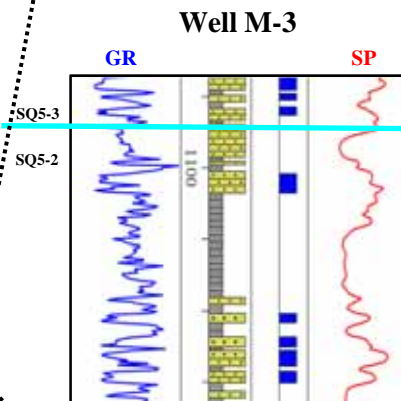
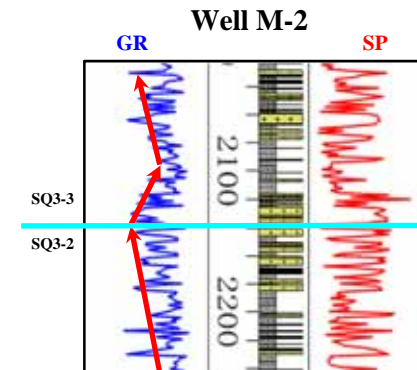
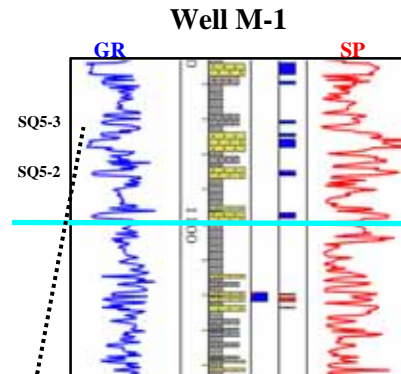


General

Stratigraphy Chart

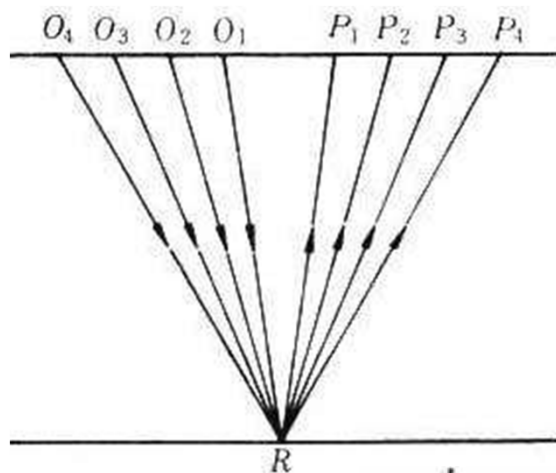


Modified by Ke, 2014



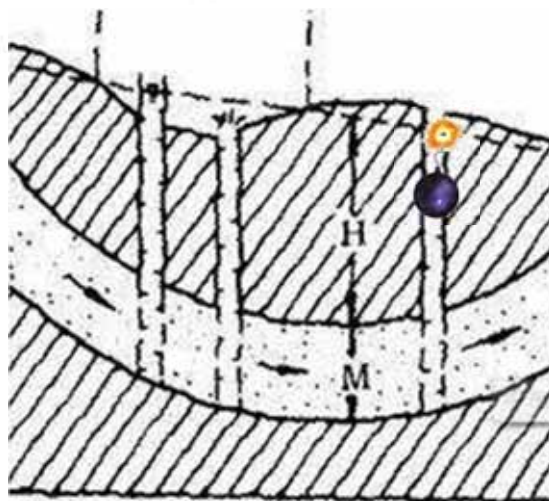
General

- Limits of acquisition condition



Low number of covering number and shore offset

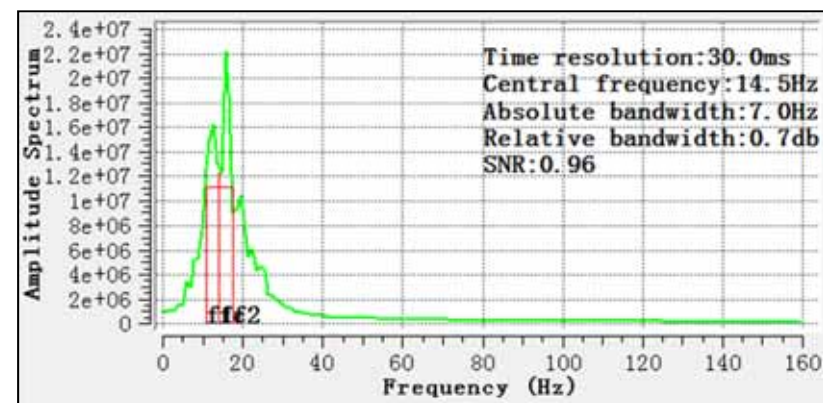
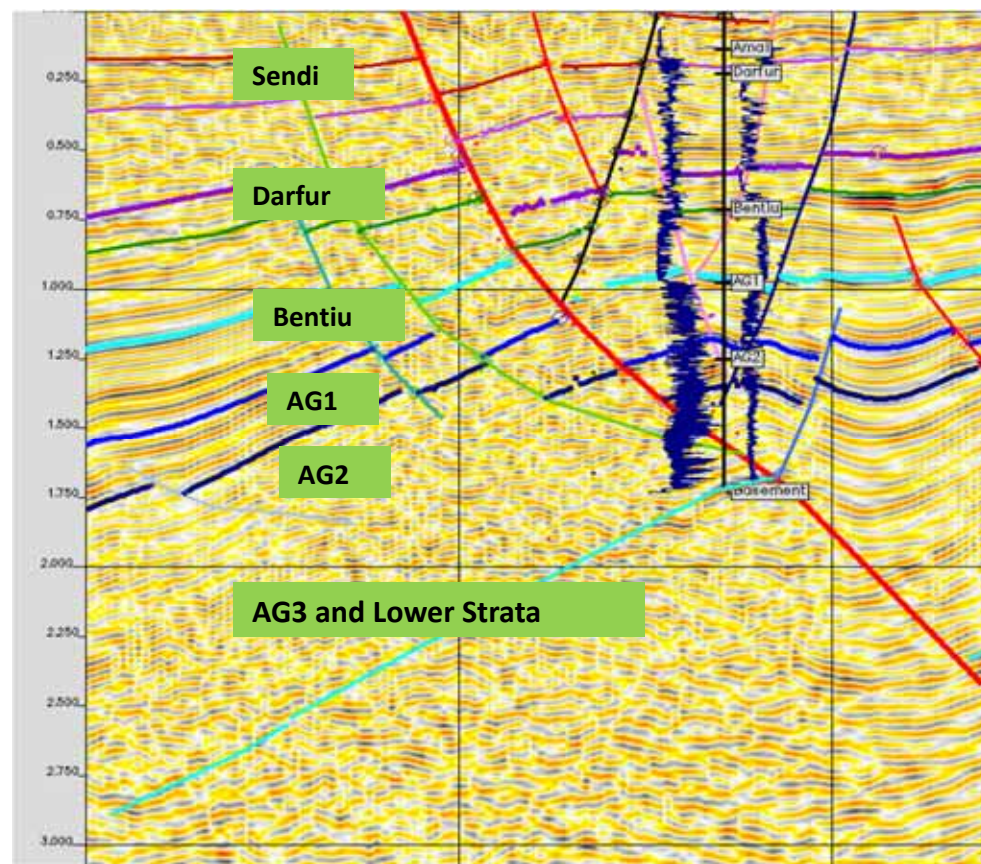
Fire position is higher than underground level, energy decreased rapidly.



General

- Seismic data quality led to poor structure identification

From AG to basement: Quality is fair to poor, hard to identify small fault and get clear image of structures



Effective Resolution of formation is $1/4 * \lambda = 43$ meter

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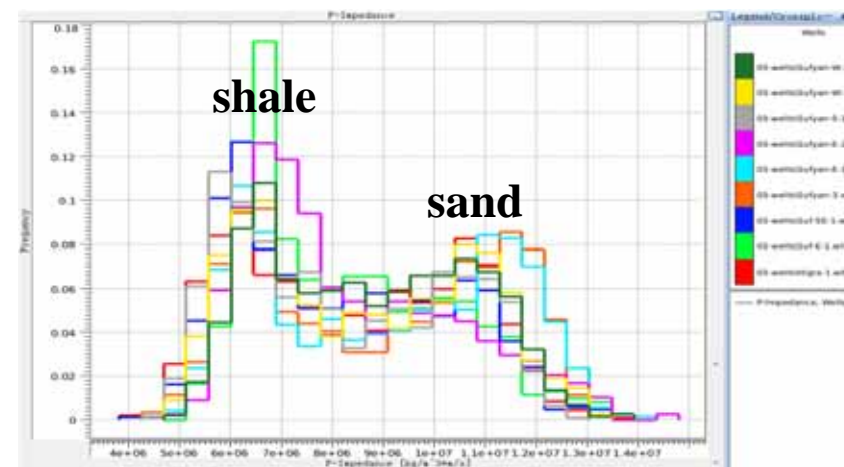
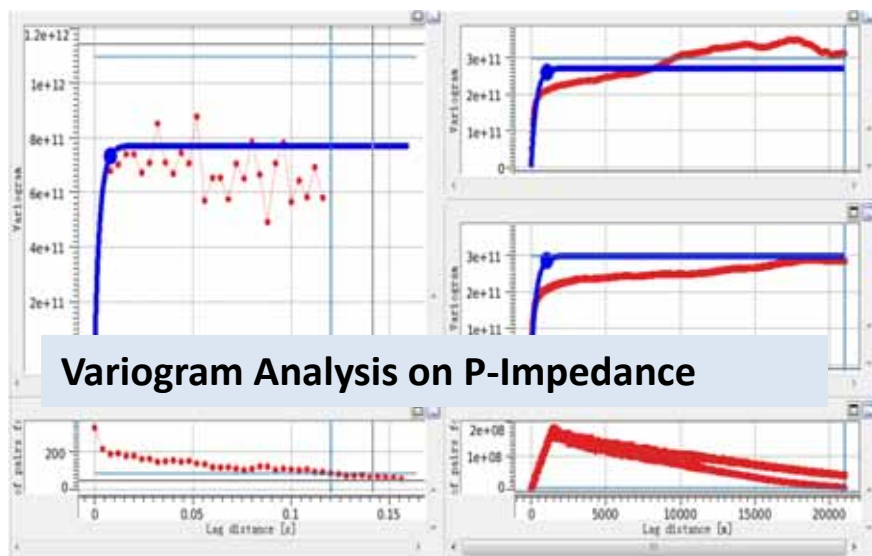
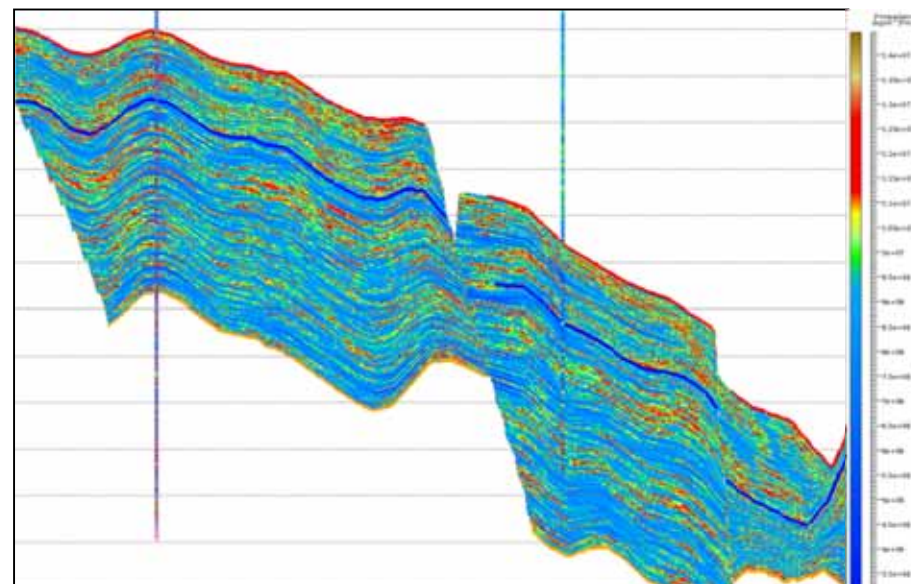
2.Method&Solution

Limits on traditional accurate thin layer prediction

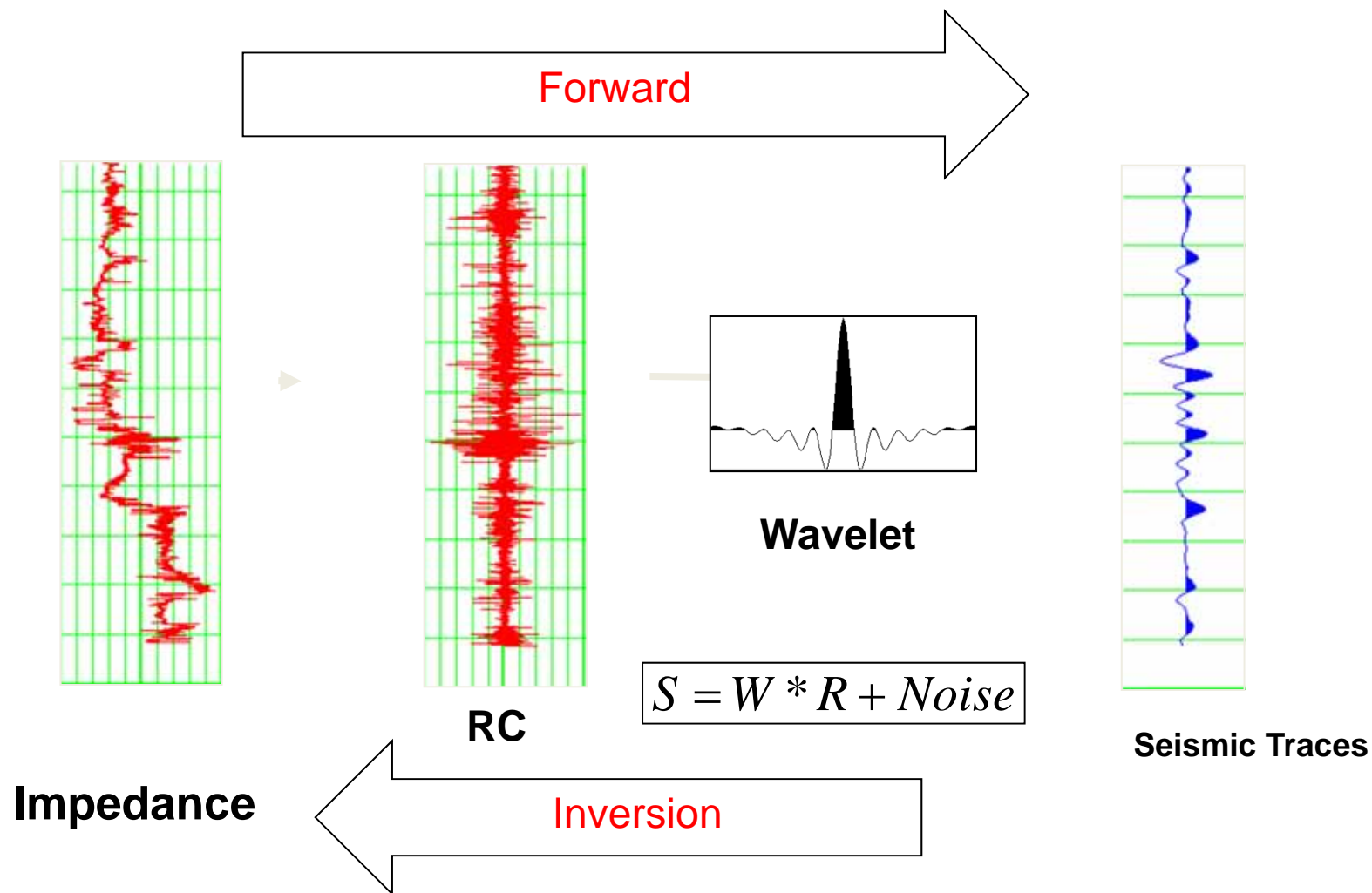
Method : Geostatistics Inversion

Limits:

- 1) Enough well number in each block
- 2) High quality of seismic data
- 3) Only P-impedance could be used for inversion



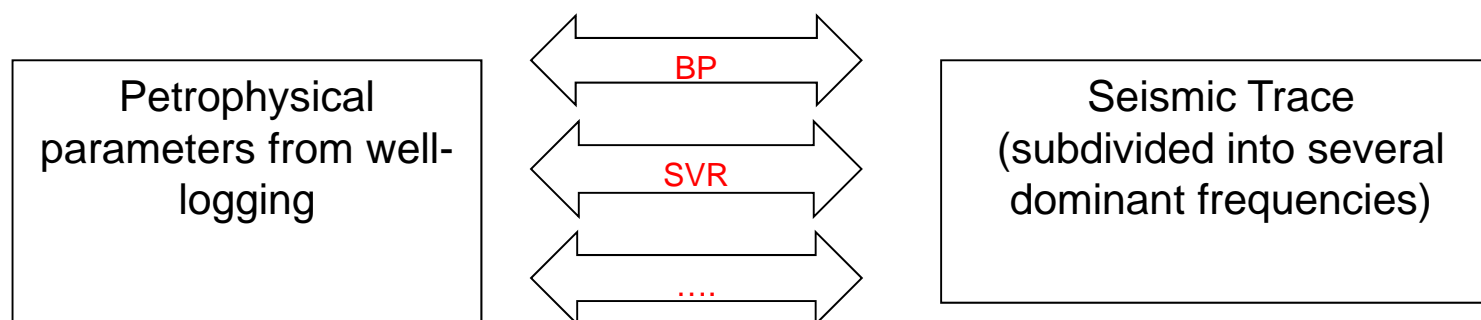
2.Method&Solution



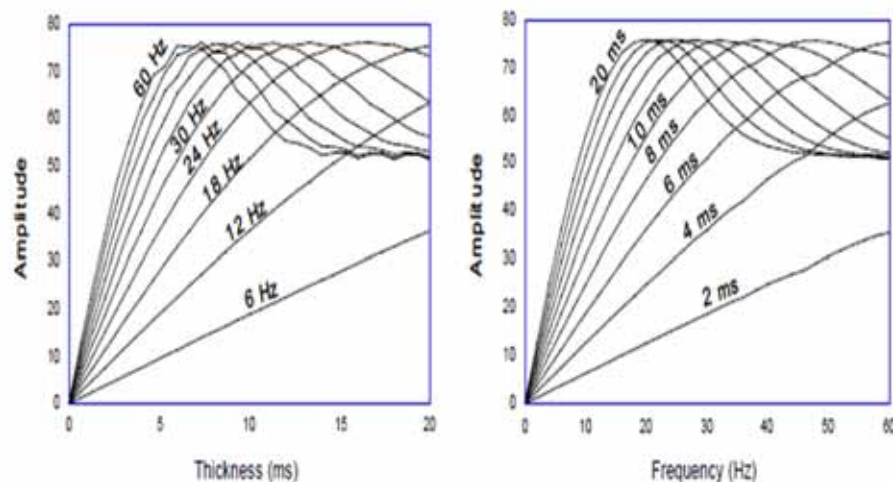
Traditional model based impedance inversion

2.Method&Solution

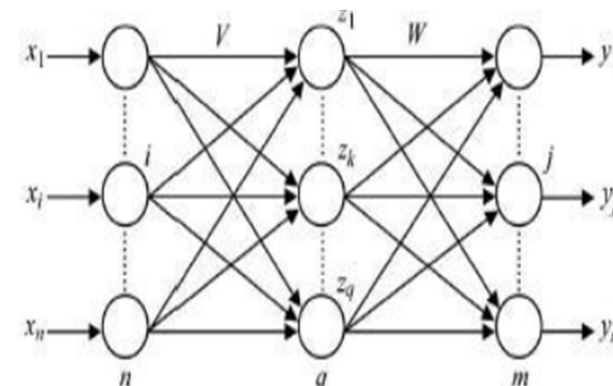
In some area, seismic data is not good enough for traditional inversion, **NEW METHOD** should be used to predict reservoir



Setup **non-linear** relationship between wells and seismic trace



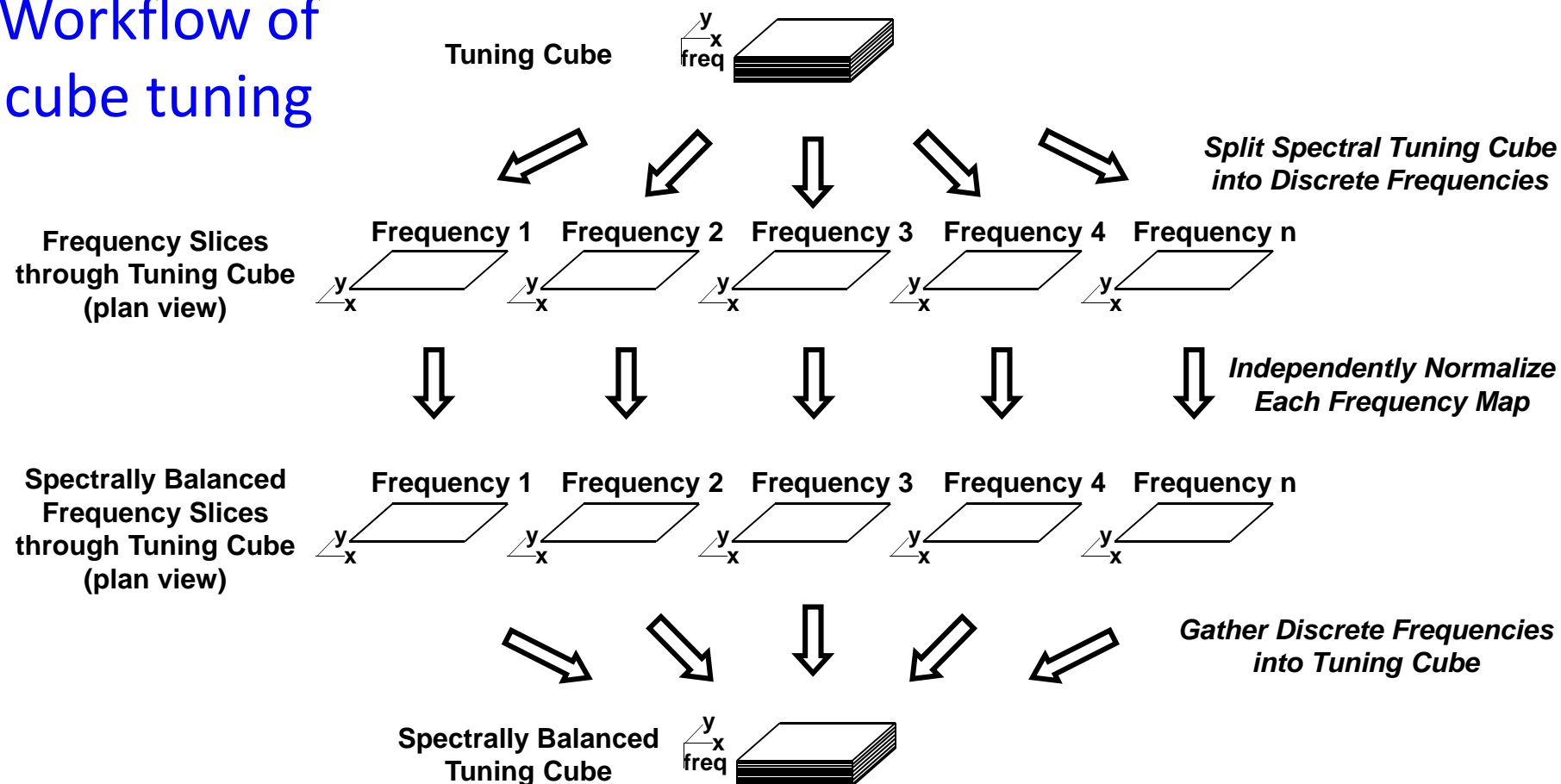
Input Layer Middle Layer Output Layer



Principle of Back Propagation

2.Method&Solution

Workflow of cube tuning

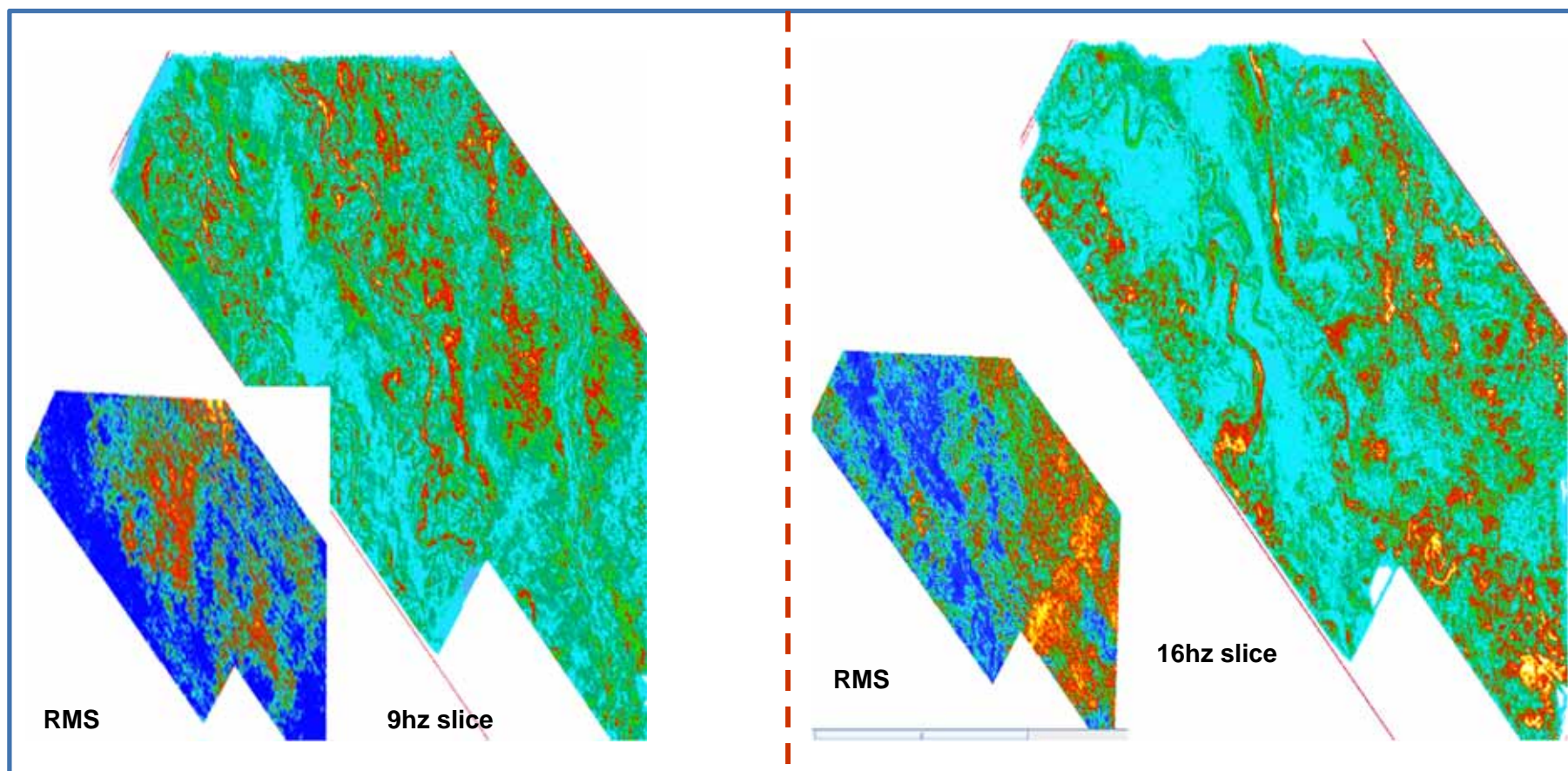


(Partyka 1999)

2.Method&Solution

STEP:1

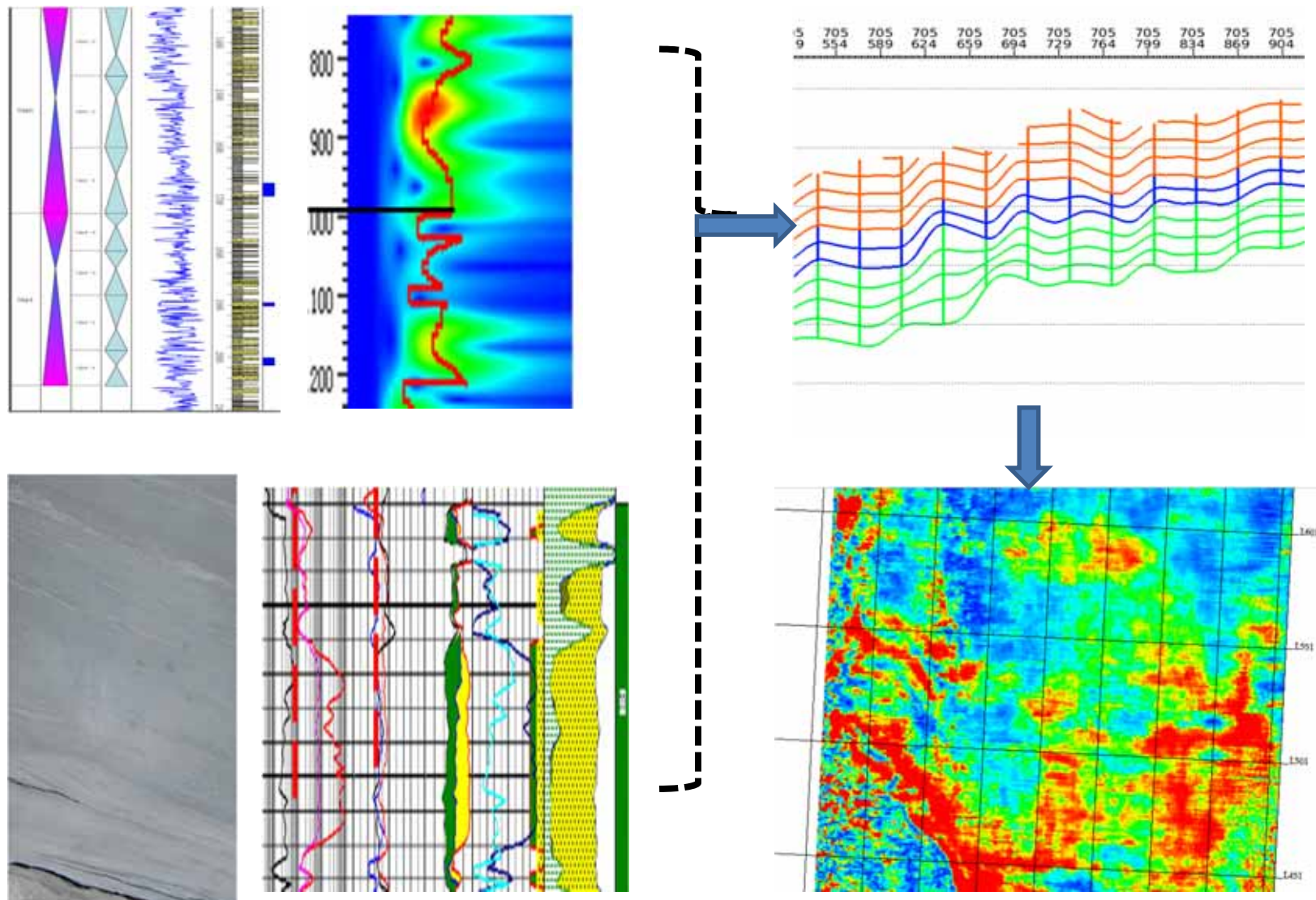
Sub-water channel identification using Spec-Decom, in Bengal submarine fan



Late Miocene

Late Pliocene

2. Method&Solution



2.Method&Solution

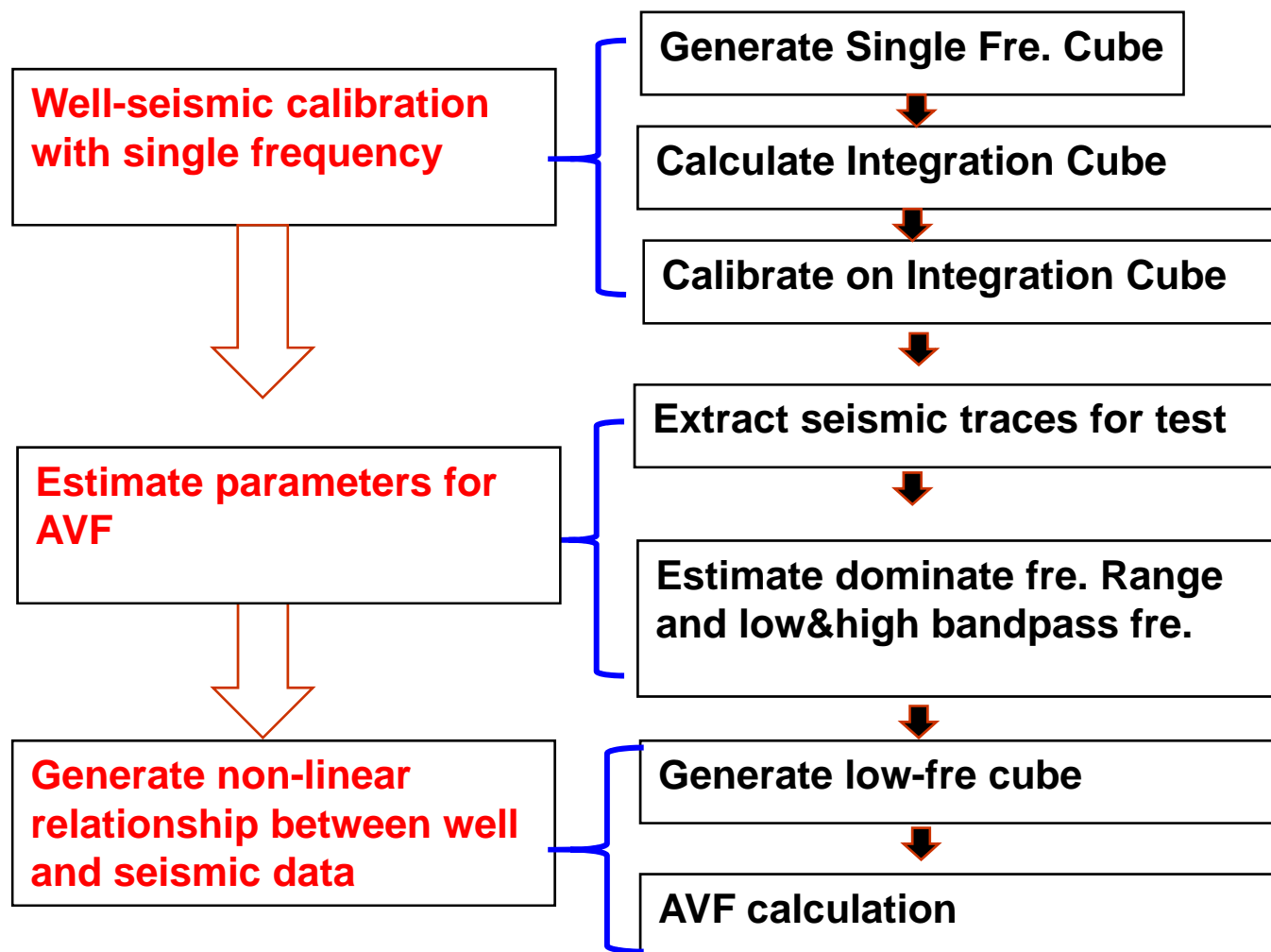


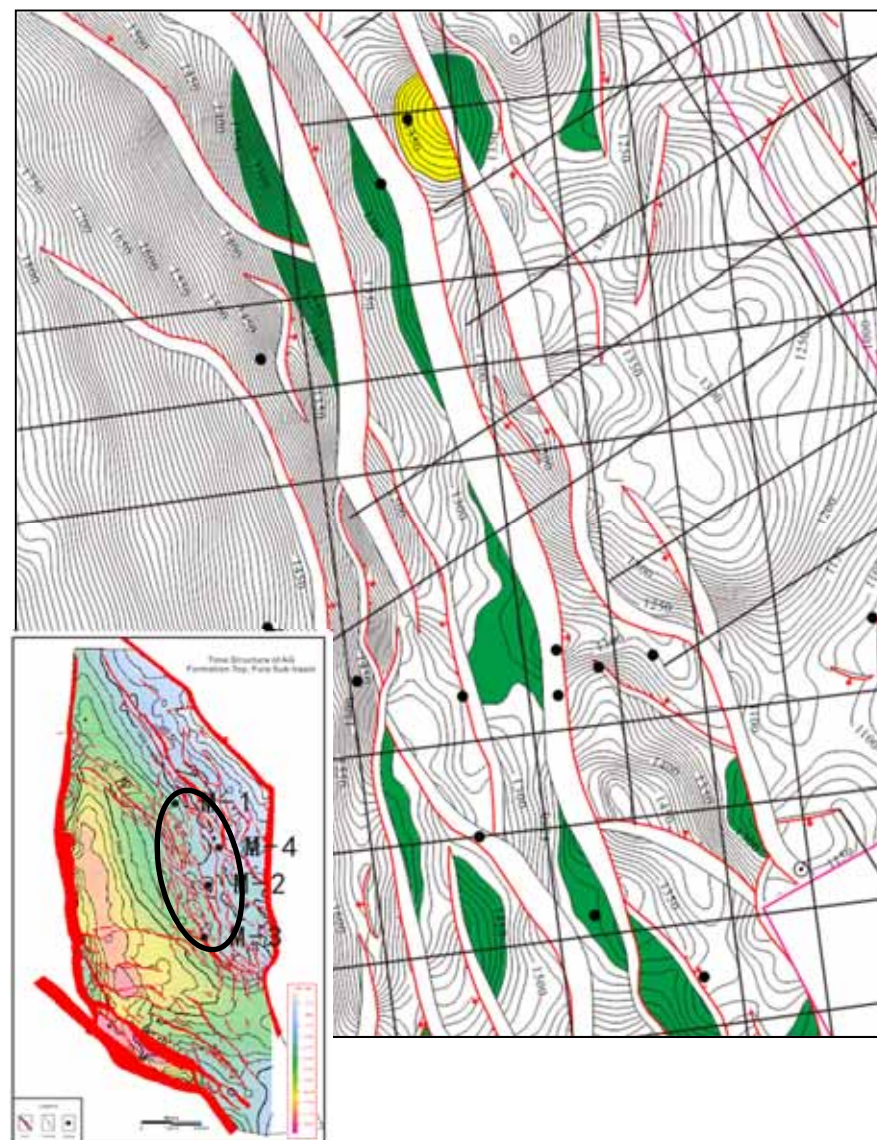
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3. Case Study

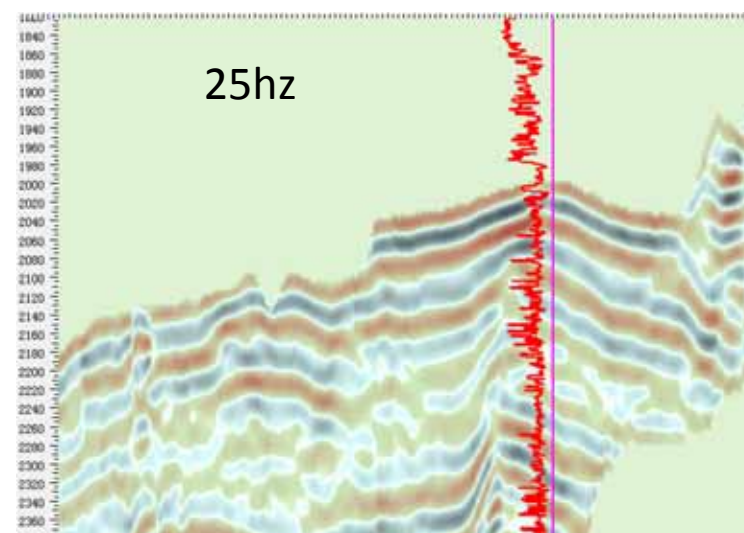
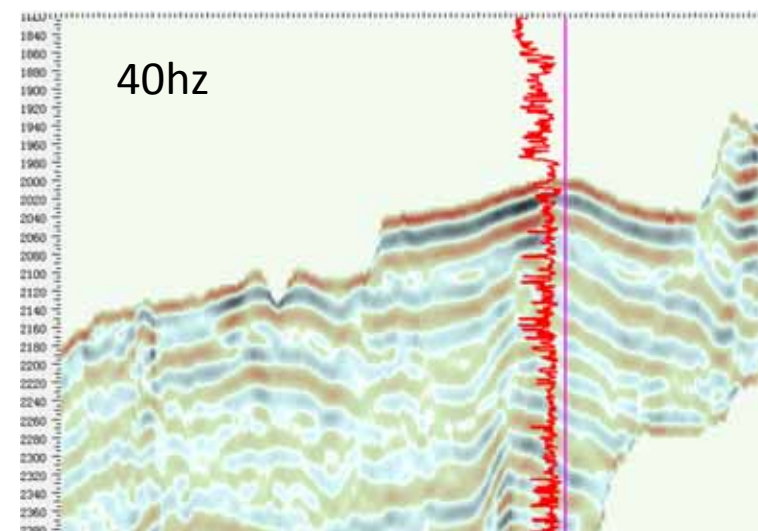
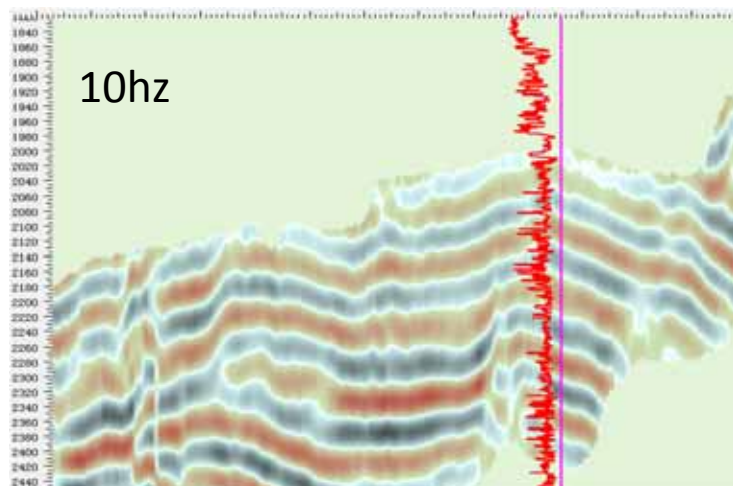
M oilfield is one of the largest oil production area in Fula sub-basin.

Main production zone is Abu Gabra formation in upper cretaceous with feature of thin sandstone imbedded by shale



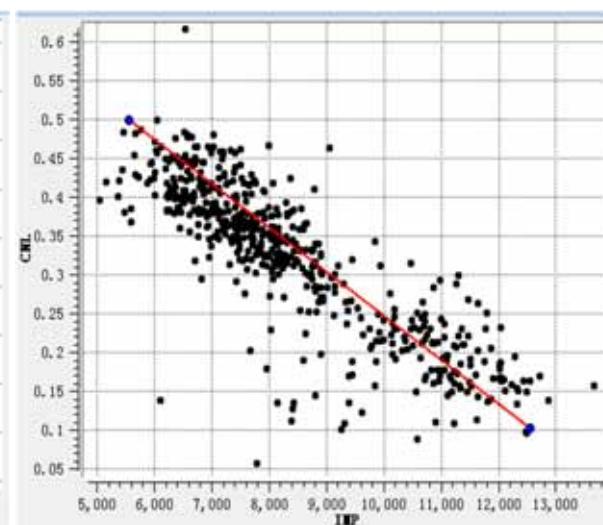
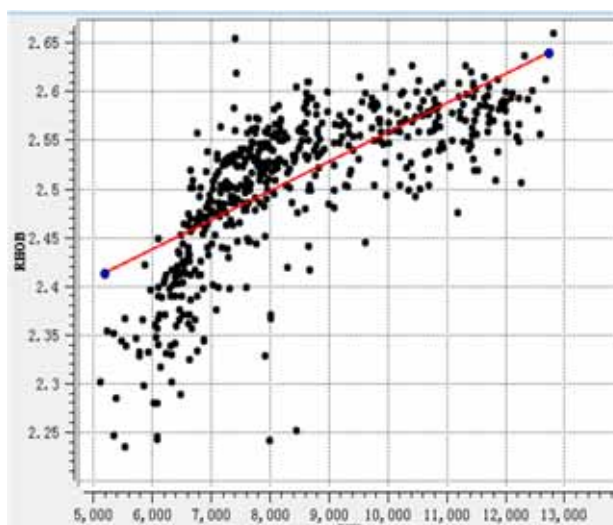
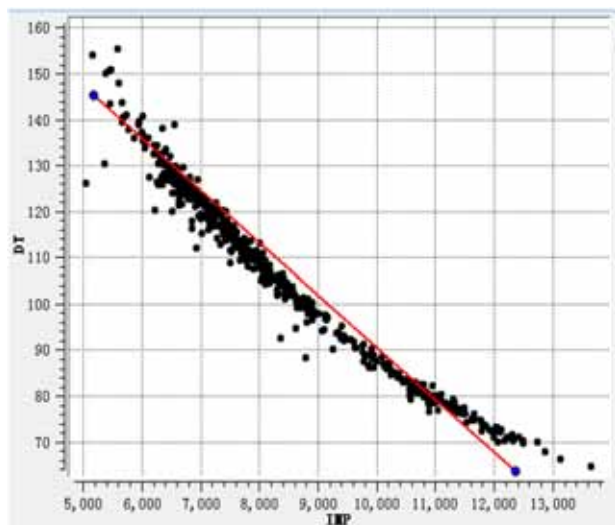
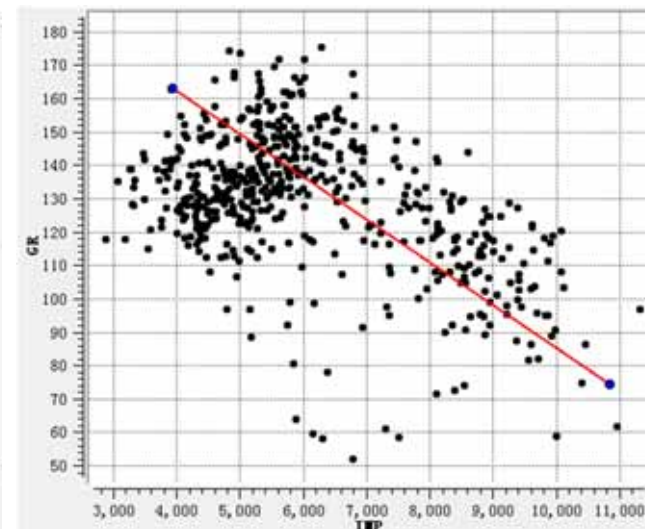
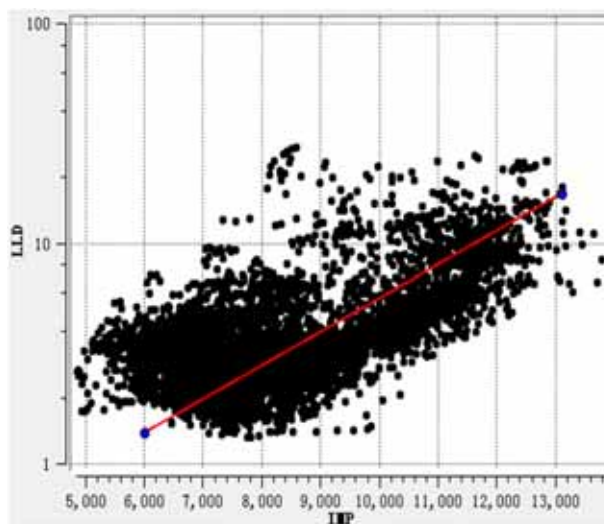
3. Case Study

10,25,40 hz are selected as spectrum decomposition parameters, each of them is corresponding certain formation thickness



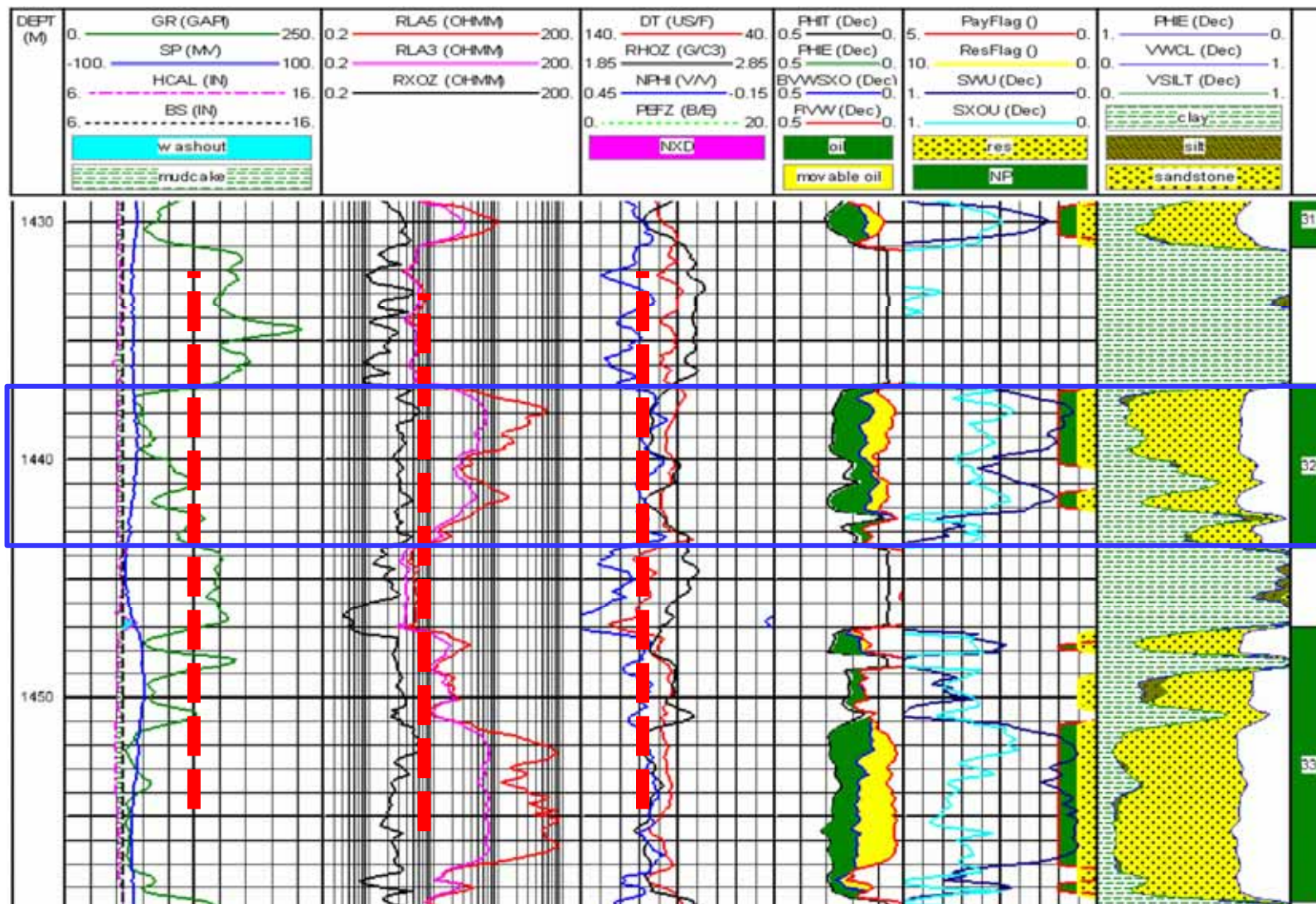
3. Case Study

Sensitive Curves Analysis
based on crossplot
reveals that GR, RHOB,
CNC curves have good
correlation with P-
Impedance curve.



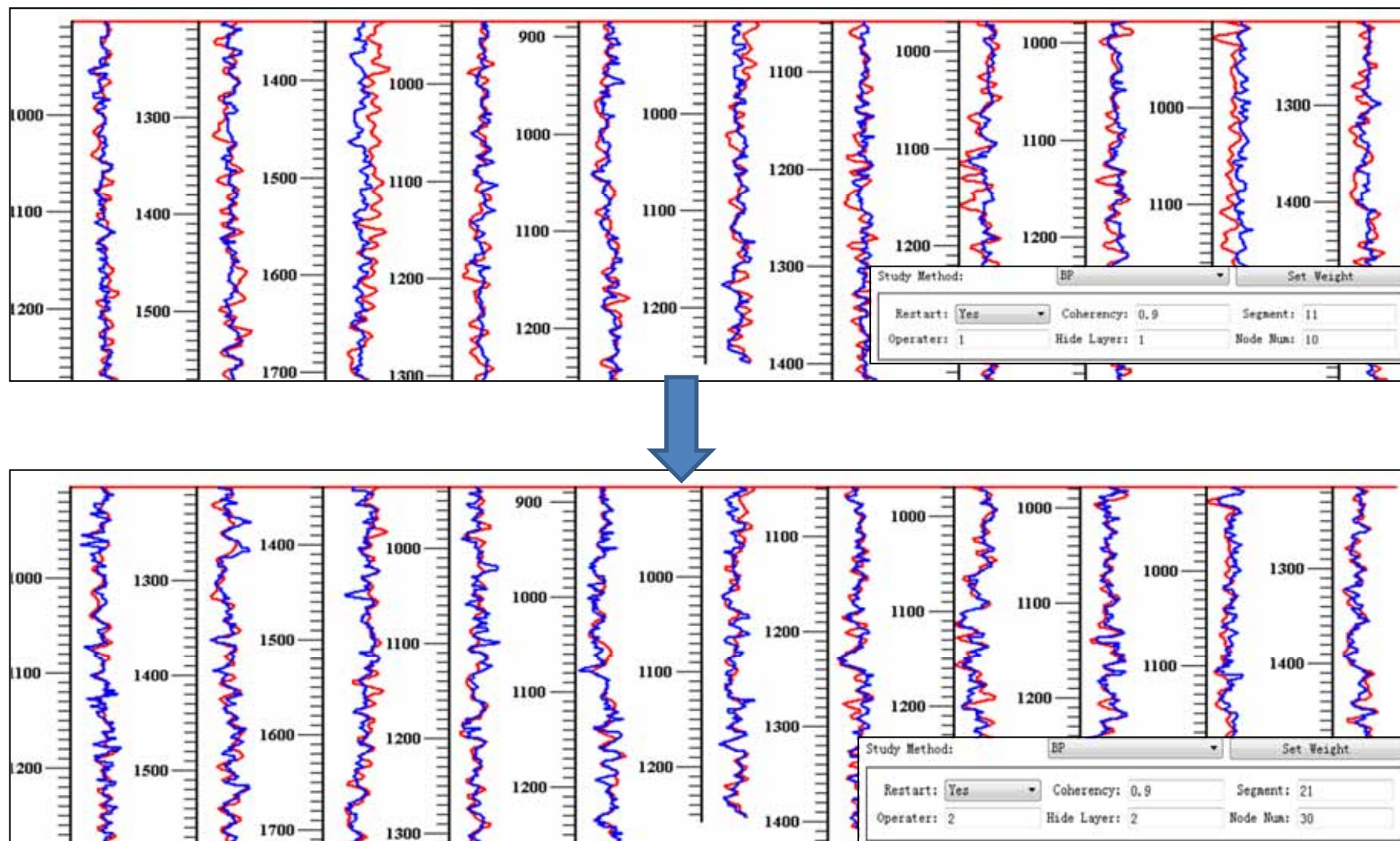
3. Case Study

Identify cutoff value of sensitive curves

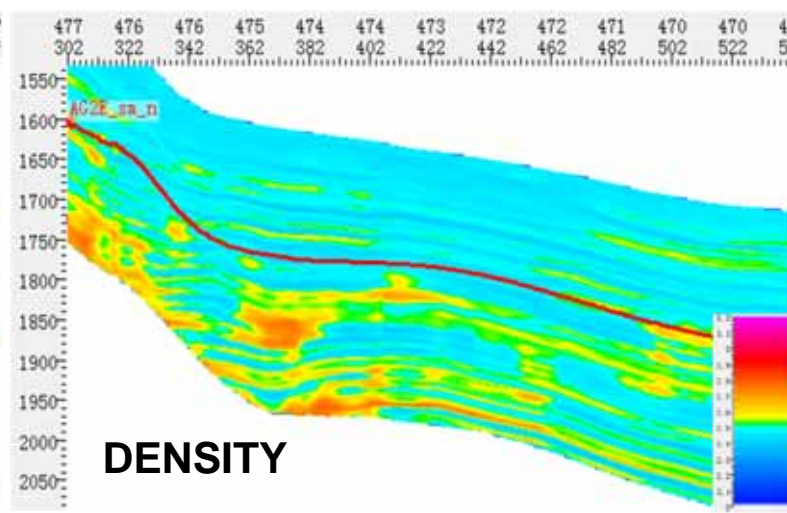
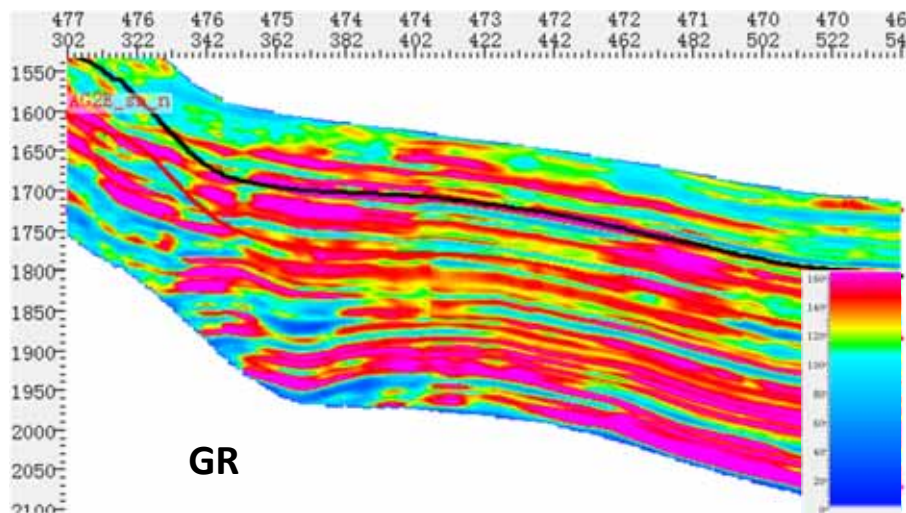
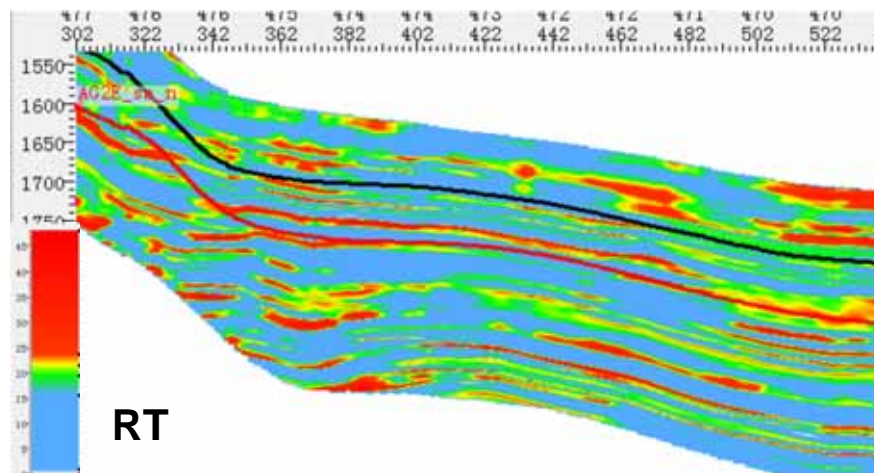
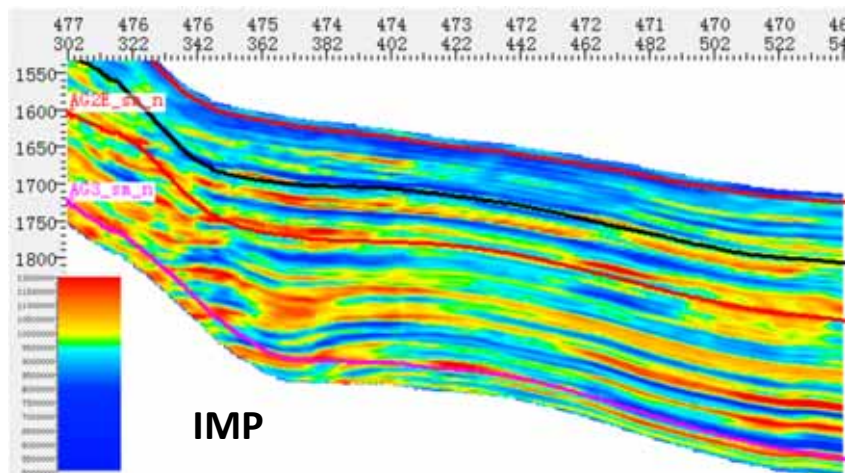


3. Case Study

Accurate waveform matching between well logging curves and seismic wave

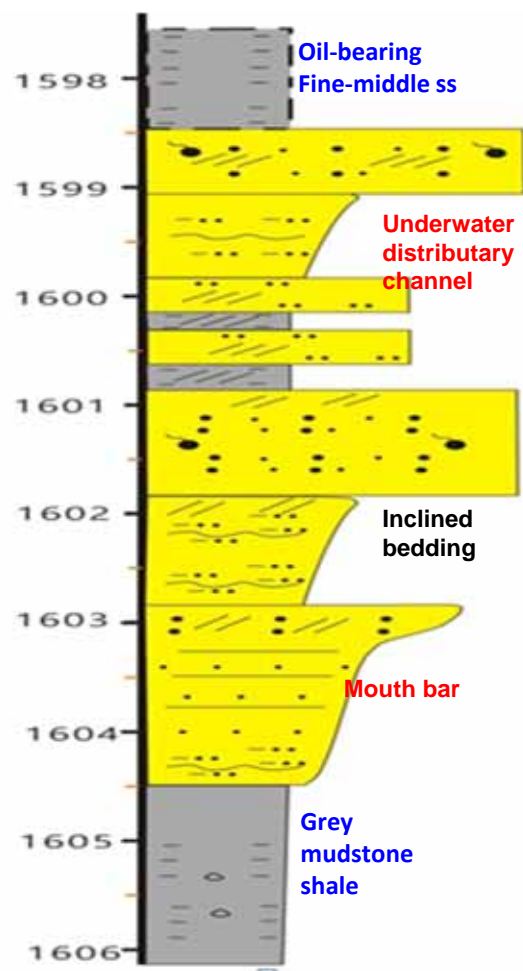


3. Case Study



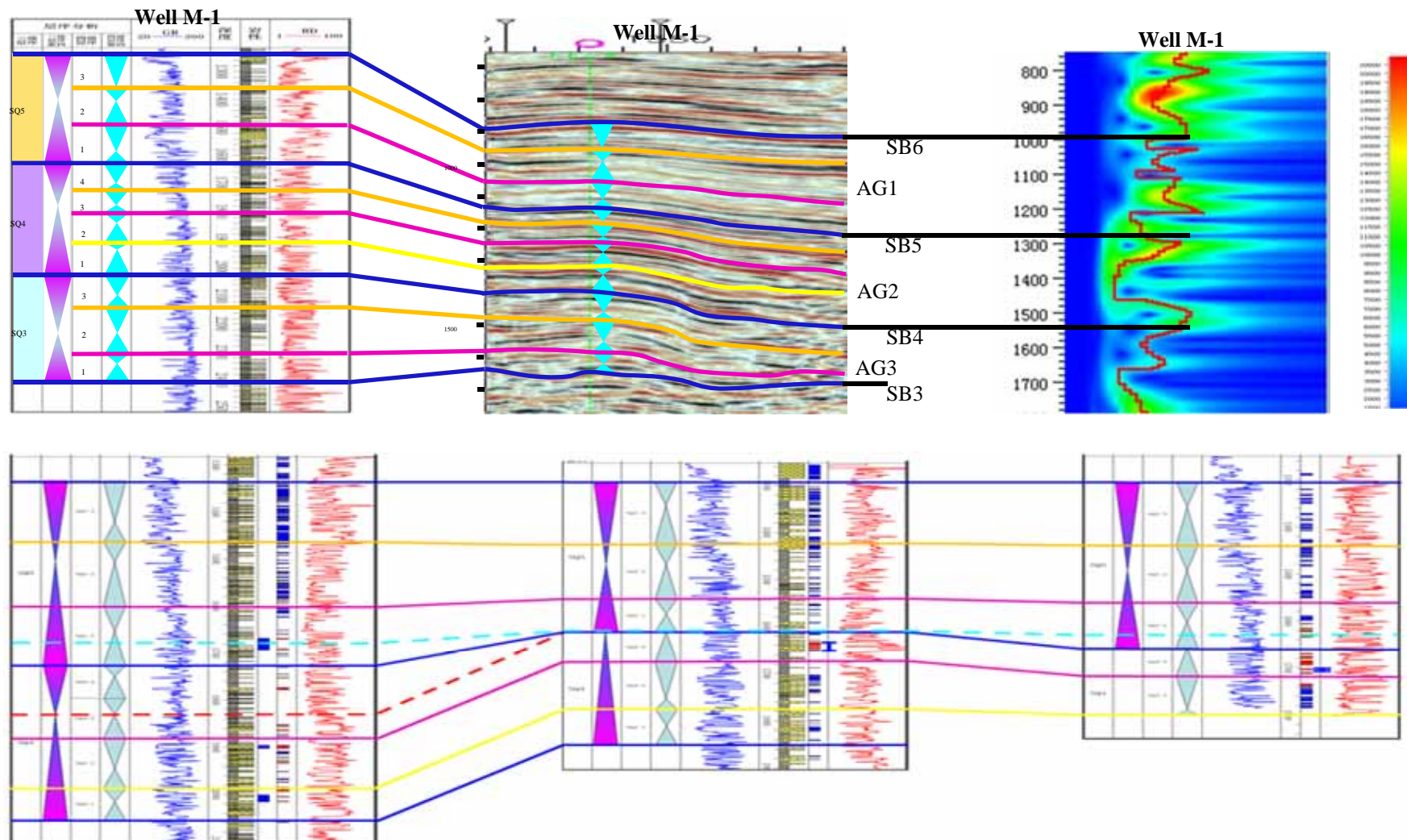
3. Case Study

Well core sample shows AG formation belongs to delta front and shallow lake sedimentary environment



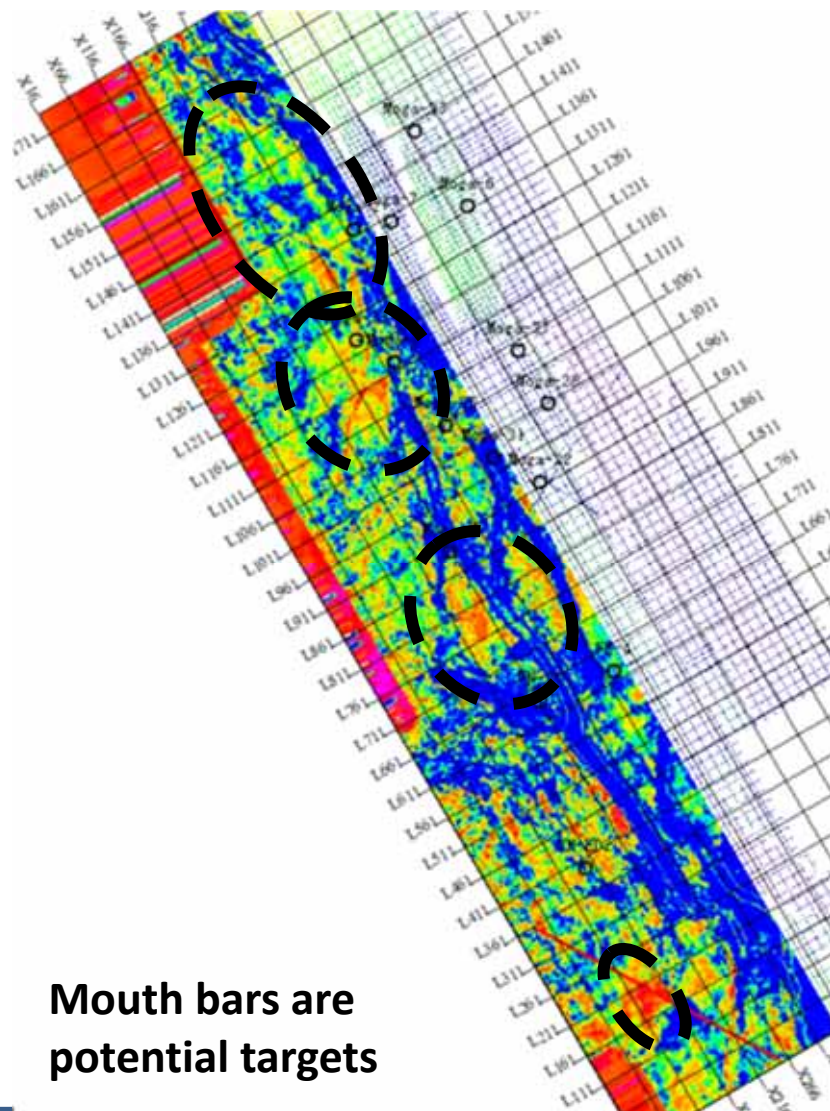
3. Case Study

Subdivide target formation into several forth-level sequences



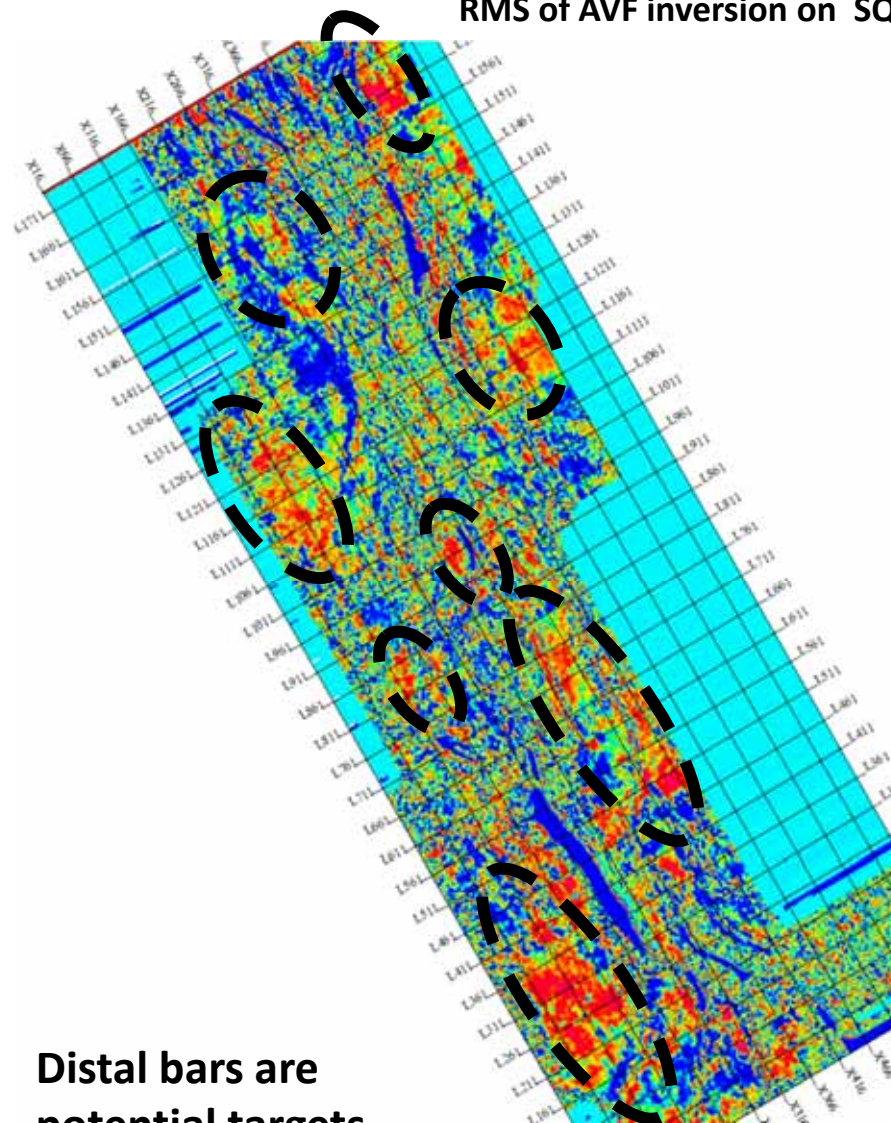
3. Case Study

RMS of AVF inversion on SQ5-2



Mouth bars are potential targets

RMS of AVF inversion on SQ4-3

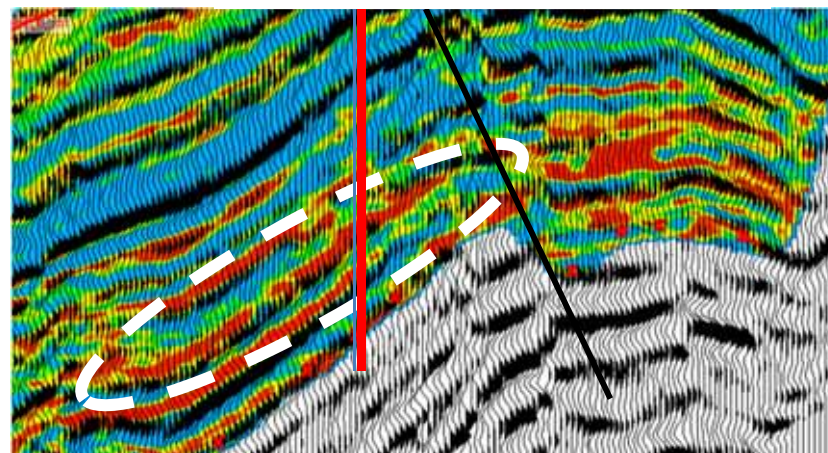


Distal bars are potential targets

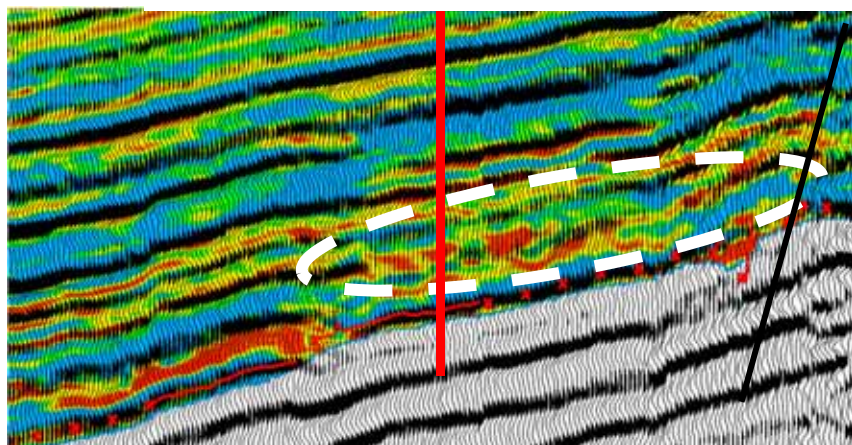
3. Case Study

Some successful drilled target with good oil discoveries in Fula Sub-basin, most of which are structure-stratigraphic complex traps.

Distal bar/sheet sand



Underwater distributary channel



River mouth bar

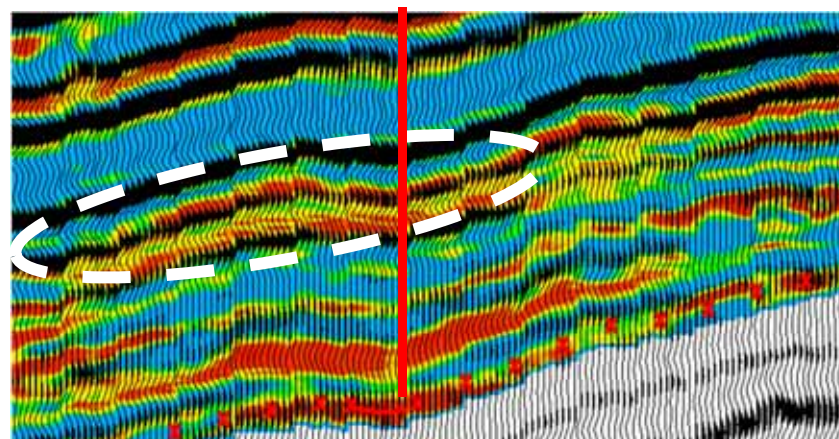


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4. Discussion

- 1) Traditional thin layer prediction method has its own limits in area with low seismic data quality caused by poor acquisition limits, thin sandstone layers can not be predicted accurately.
- 2) Different from other traditional inversion, BP-ANN inversion set up a kind of un-linear relationship between well-logging curves and seismic data via waveform
- 3) High level stratigraphic sequence subdivision is the base of accurate stratigraphic slice
- 4) Exploration experiences in Fula sub-basin has proved that the BP-ANN inversion is effective and lead to good oil discoveries
- 5) Further works should be done to improve the stability of the ANN network used for prediction.

**Thank for cooperation of the experts from
Petro-Energy E&P and RIPED, CNPC**

Thank You !

Together We Find More Oil

