# Application of Spectral Decomposition Technique in Reservoir Exploration in the Junggar Basin of West China*

**Cai Gang[1], Su Mingjun[1], Yao Qingzhou[1], and Gong Honglin[1]**

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## Abstract

Frequency spectrum decomposition technique is a frequency based reservoir interpretation method. As an advanced high-definition imaging technique of discrete geologic bodies, it can be used to detect the discreteness of thin layers and geologic bodies in the 3D survey areas by using seismic data. Seismic data in the time domain can be converted into frequency domain through Discrete Fourier Transform (DFT). The converted amplitude spectrum can be used to detect the variability of temporal bed thickness, while the phase spectrum can be used to indicate the lateral discontinuity of geologic bodies.

The Jurassic in the central Junggar Basin is a sequence of meandering river or braided river delta deposits, but the dominant frequency of the seismic data is relatively low, so it is difficult to describe the lithologic and stratigraphic traps using conventional methods. It has been successfully used to identify channels, lithologic boundaries, faults and stratigraphic denudation line in several 3D survey areas in the Junggar Basin.

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# OUTLINE

- **BASIC PRINCIPLE**
- **APPLICATION EXAMPLES**

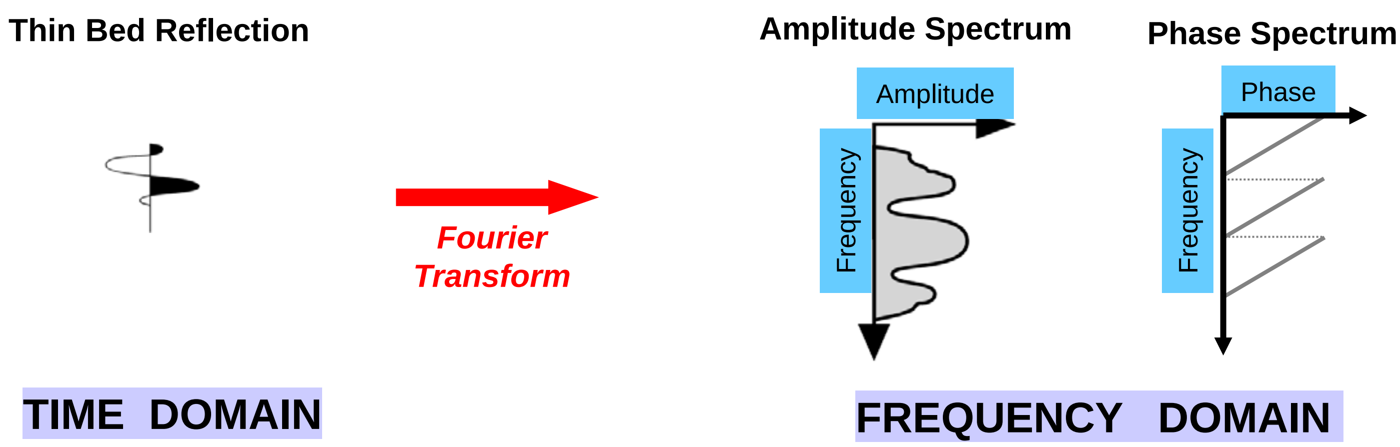
  a、 Identifing Channels

  b、 Identifing Stratigraphic Trap

  c、 Identifing Lithologic Trap

- **CONCLUSIONS**

# Basic Principle

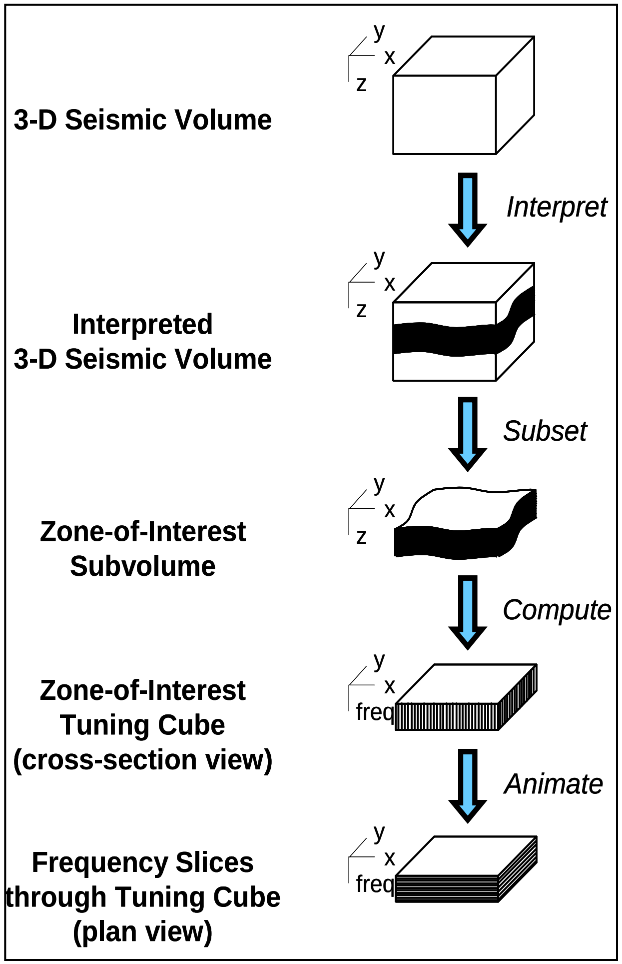



**Seismic data in time domain can be converted into frequency domain through Discrete Fourier Transform (DFT).**

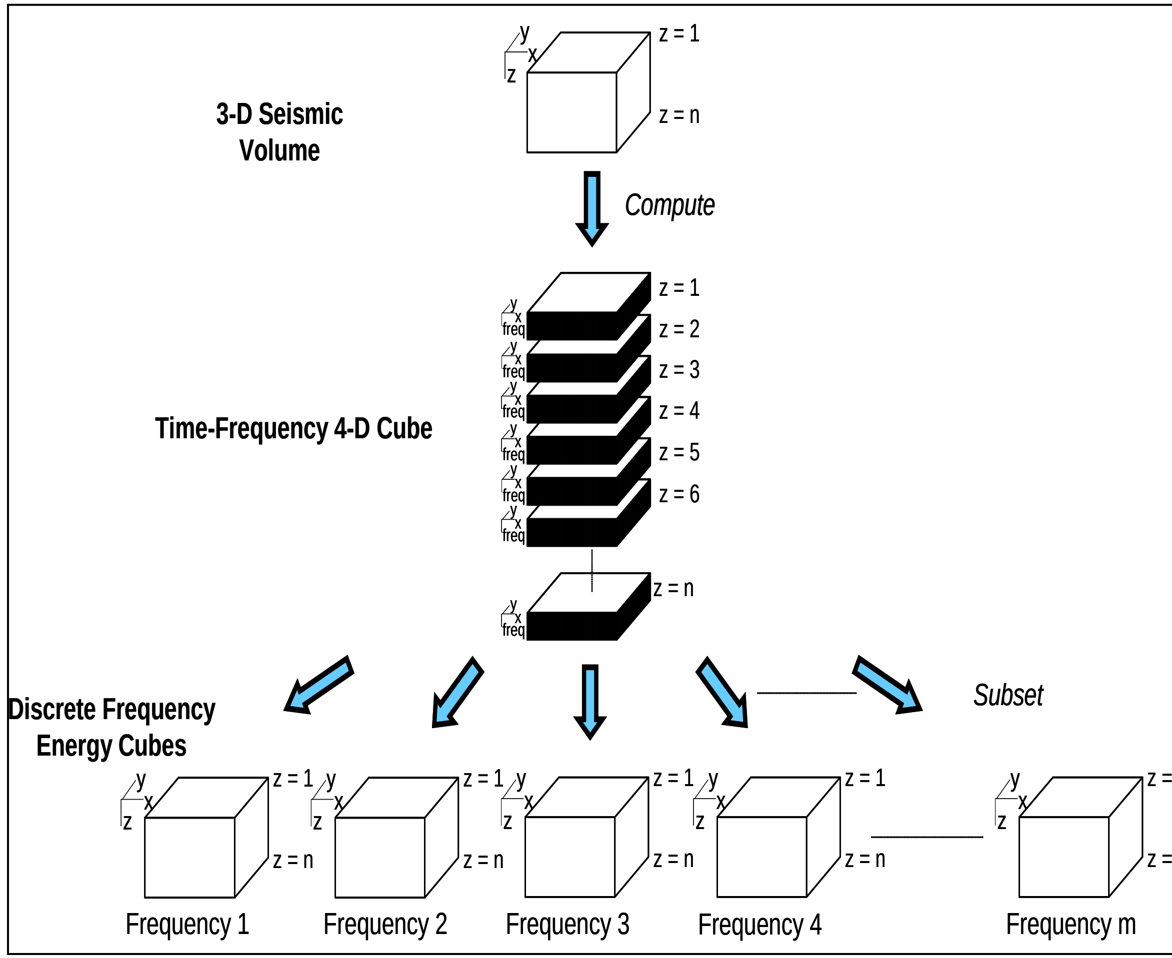
**The converted amplitude spectrum can be used to describe the change of the thin layer and detect the variability of temporal bed thickness, while the phase spectrum can be utilized to indicate the lateral discontinuity of geologic bodies.**

# Basic Principle

## The Tuning Cube




## Discrete Frequency Energy Cubes

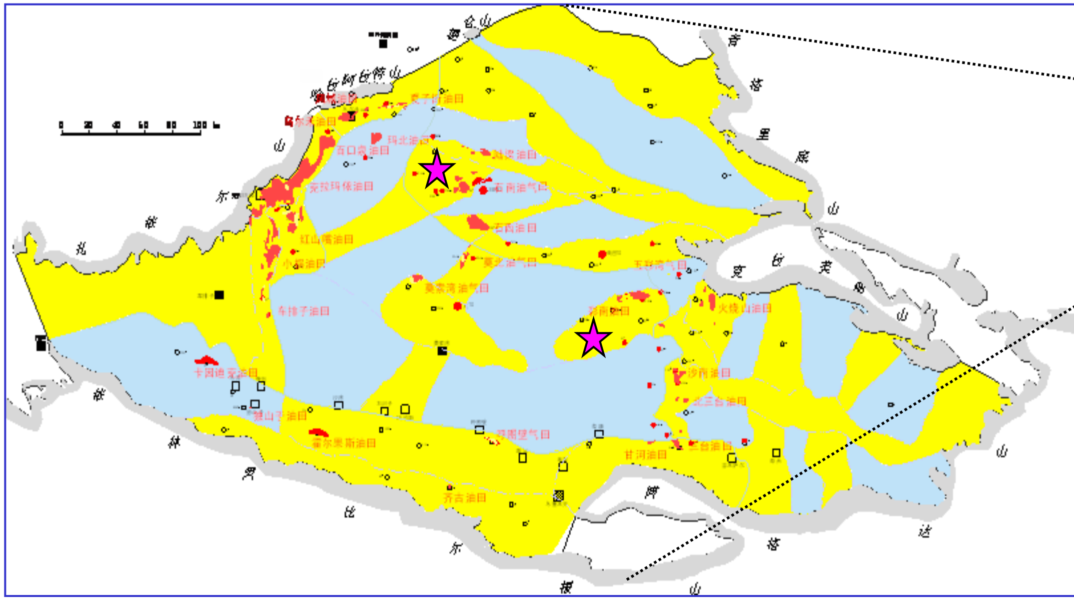


# OUTLINE

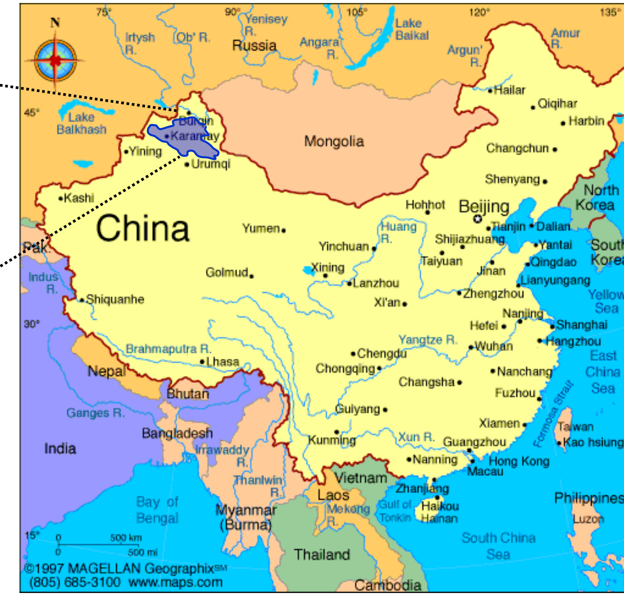
- **BASIC PRINCIPLE**
- **APPLICATION EXAMPLES**
  - a、 Identifing Channels
    E.g. C43 Well 3-D Work Area
  - b、 Identifing Stratigraphic Trap
  - c、 Identifing Lithologic Trap
- **CONCLUSIONS**

# APPLICATION EXAMPLES

## Junggar Basin



## Map of China

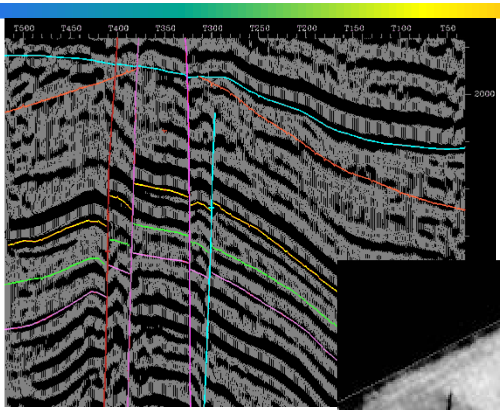



◆The Junggar Basin is one of the richest hydrocarbon-bearing basin in China. It is about 380,000 square kilometers located in western China between Altai Mountains and Tianshan Mountains, and it is nearly triangular in shape. There is a desert in the middle, covering 36.9% of the basin. General elevation is about 400m, Terrain is high in east, low in west.

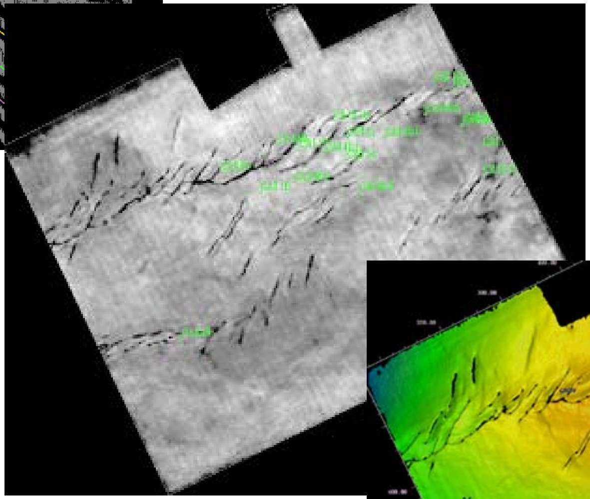
◆After half a century's exploration in the basin, a large number of oil/gas fields have been found. In recent years, exploration of subtle oil/gas reservoirs has become increasingly difficult, since the subtle reservoir has been regarded as the main exploration targets. In sense of this, the widespread application of seismic interpretation and advanced technology is taken as the best choice to attain the breakthrough in the exploration of subtle reservoirs.

## a、 Identifing Channels

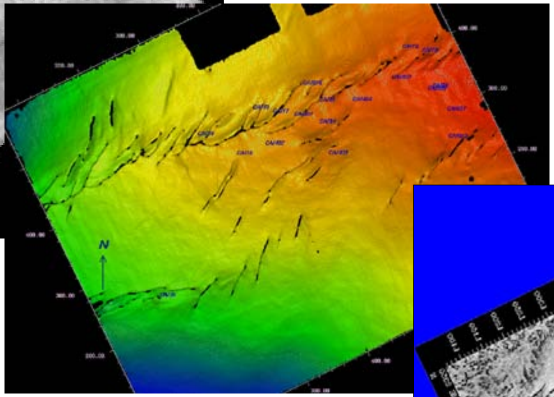
◆Combination of more information to improve the reliability of fault interpretation



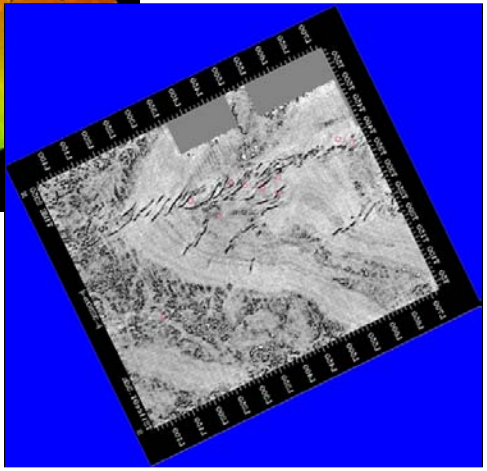
Seismic Section



Coherence Cube

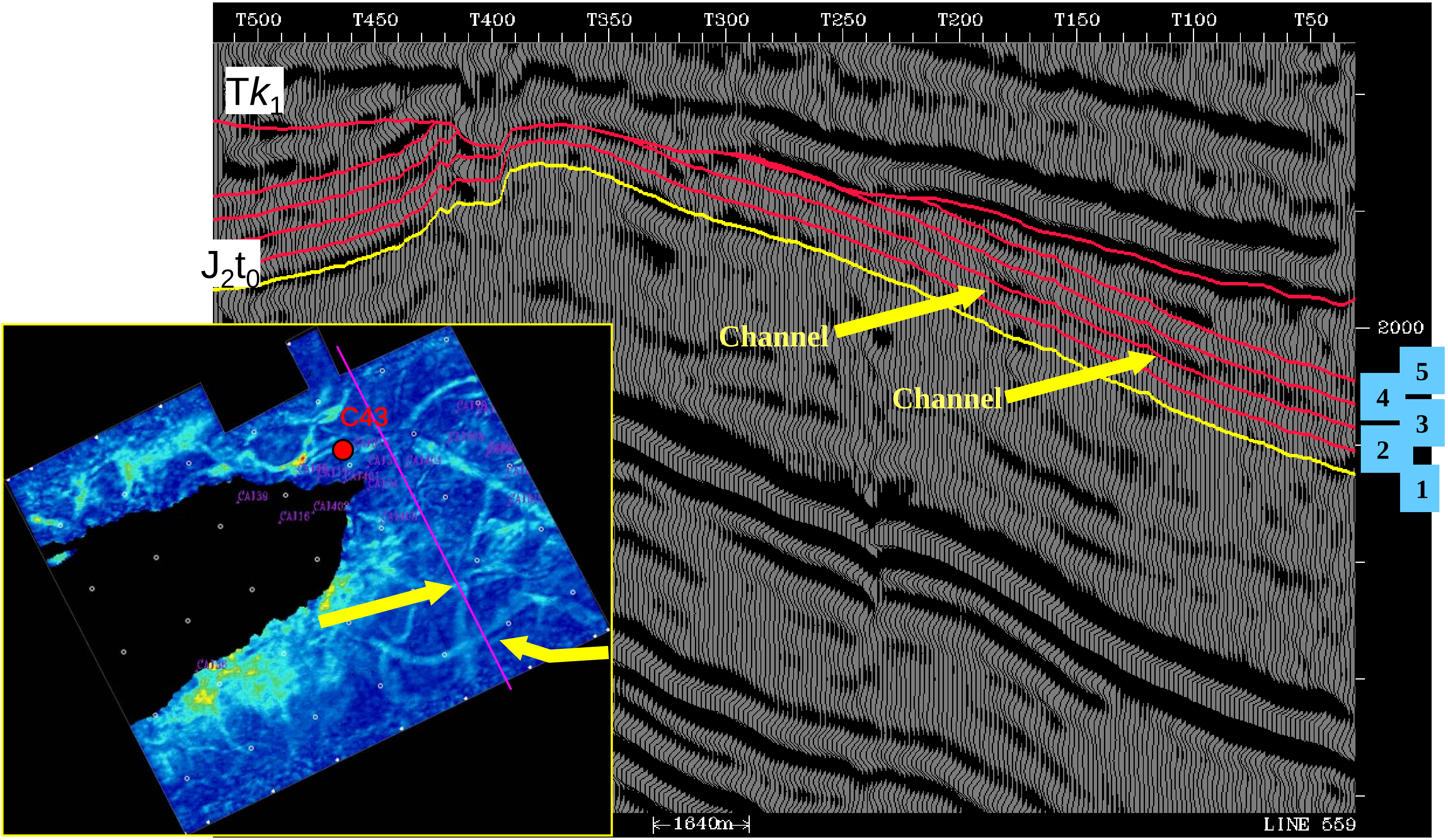


Visualization



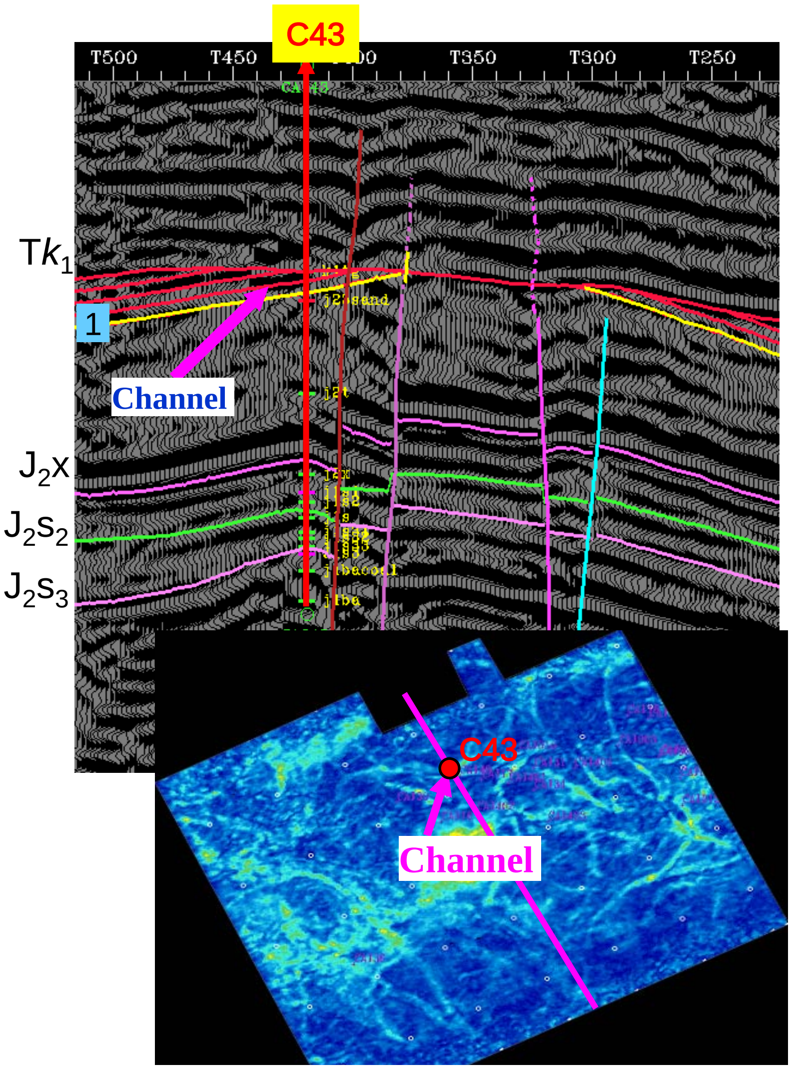
Time Slicing

◆Strong amplitude Corresponding relations between the plan and section



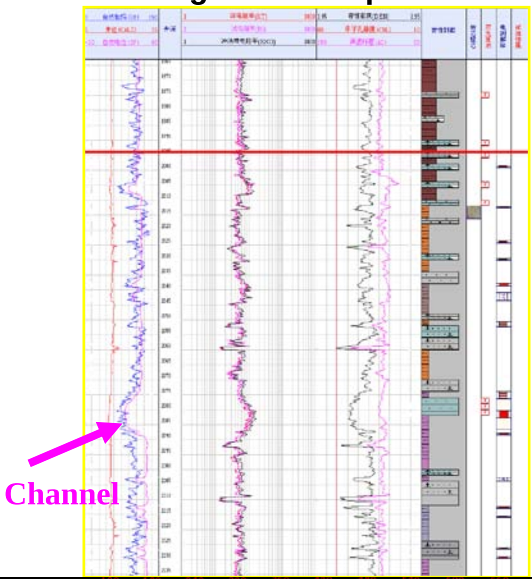

RMS amplitude Plan（between horizon 1 and 3）

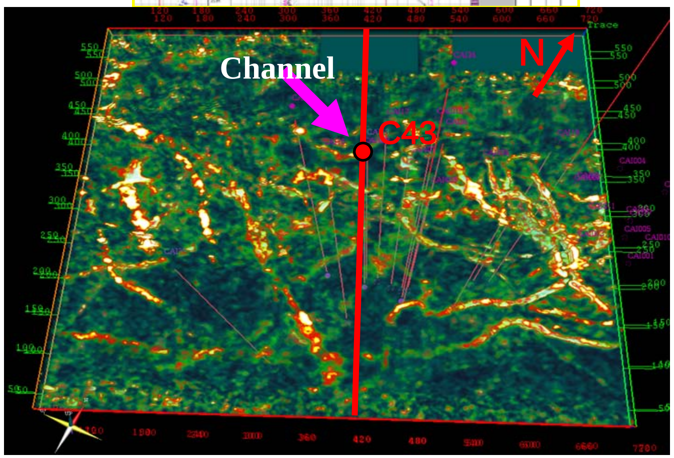
## ◆Corresponding relation of the Channel on the plan and section




RMS amplitude Plan(along 1 horizon 40ms)

C43 Integrated interpretation chart



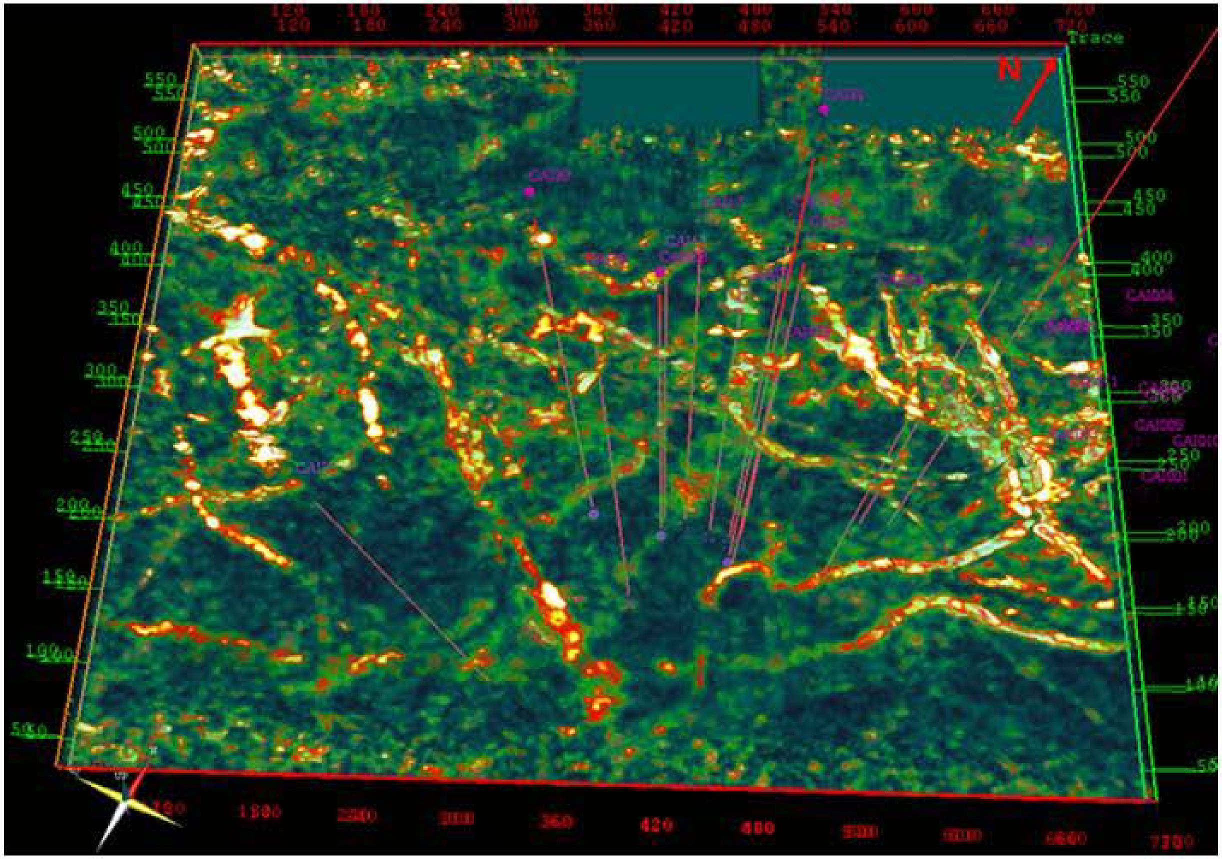




Frequency Spectrum Amplitude Plan

APPLICATION EXAMPLES

a、 Identifing Channels

◆ The amplitude plan of spectrum decomposition in Shishugou Formation



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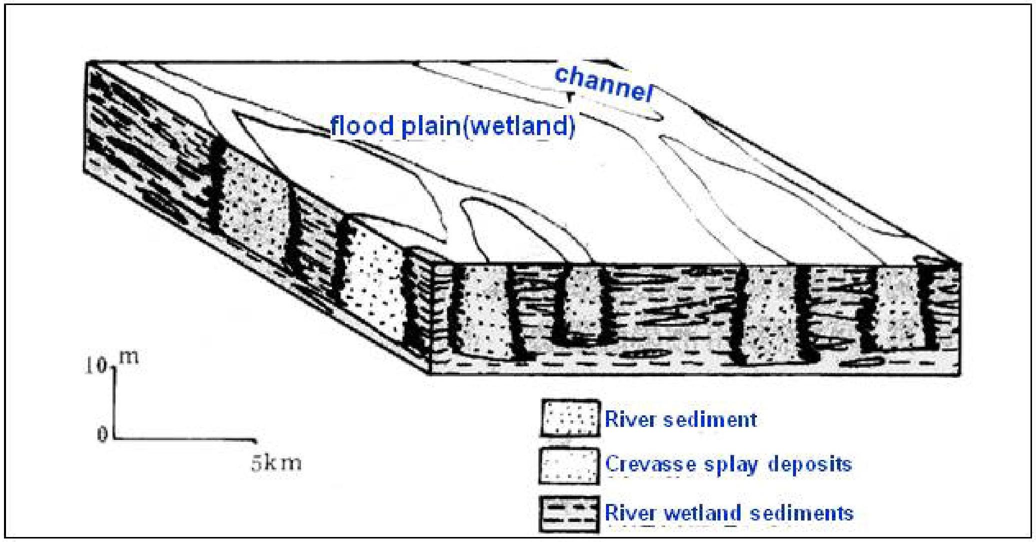
Notes by Presenter: In the amplitude plan of spectrum decomposition, Shishugou Formation shows characteristics of Network River , indicating that the area is located in the middle and lower reaches of rivers. The terrain is relatively flat and has a characteristic with curved multi-channel deposits, channel narrow and deep, flow-down net nodes. The width of deposits is in proportion to the width of channel. In the Figure 1, the light color corresponds to thick reservoir, and the color changes deep expresses reservoir thickness thins, and black background color means non-reservoir.

## APPLICATION EXAMPLES

## a、 Identifing Channels




**Braided River Sedimentary model environment map of the lower Cretaceous in Canada** (Schmitt,1980)

◆Based on research on the inversion and attribute information and well logging curves, we think Shishugou Formation is a braided river sedimentary model.

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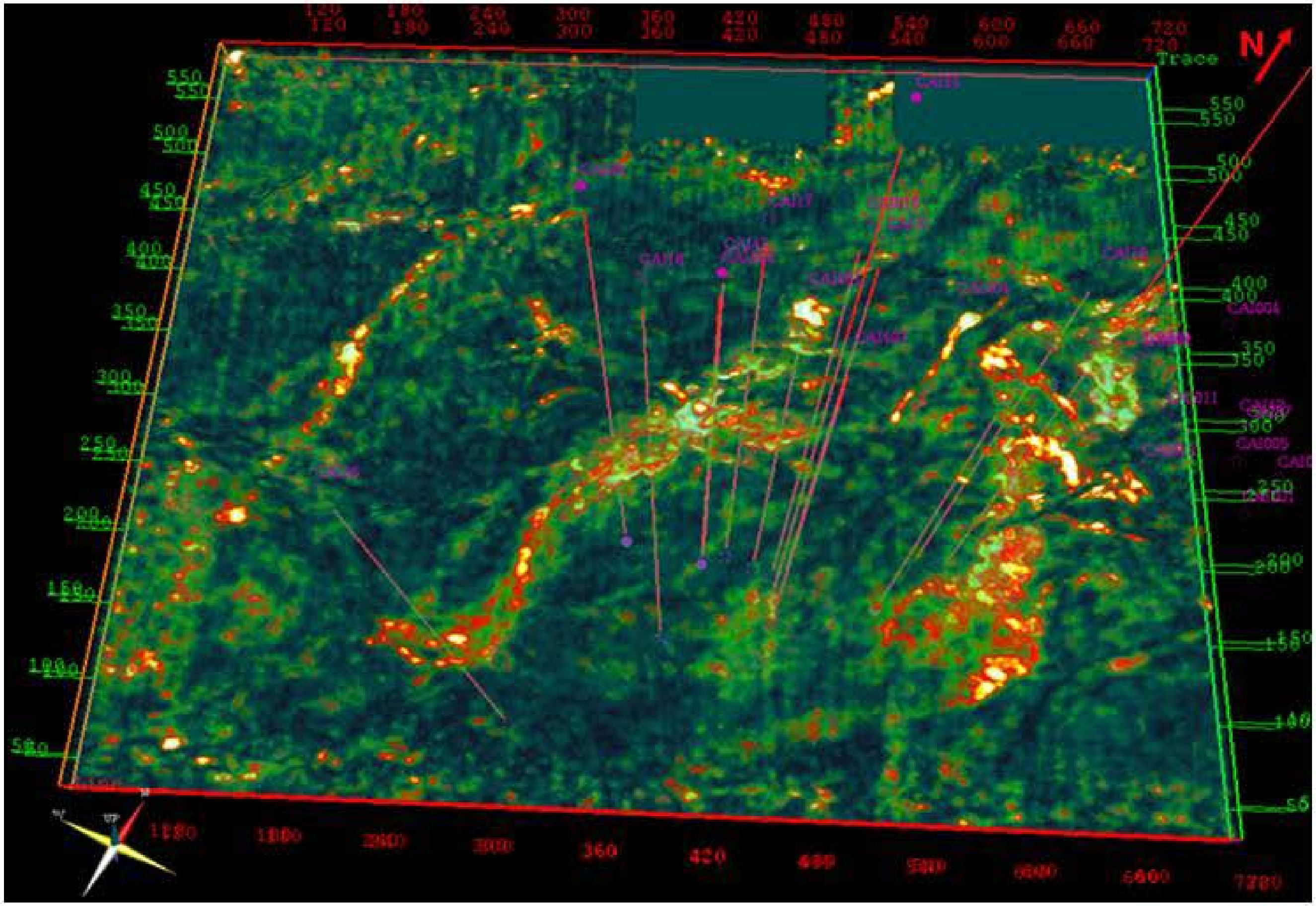
Notes by Presenter: Characteristics of braided River is a river with bends, River narrow and deep, downstream of anastomosis down, River transportation mainly to suspended load, deposit in proportion to the width and the width of the River change. Alluvial island in the River is semi-permanent and separate flood plain or wetland. Alluvial flood plain or wetland and island are mainly composed of fine material and peat, its location and size, stability, and compared to the narrow river channel, they occupy an area of about 60-90%. Network development in river middle and lower reaches of the River area.

APPLICATION EXAMPLES a、 Identifing Channels

◆The amplitude plan of spectrum decomposition in the second part of Sangonghe Formation($J_1s_2$)



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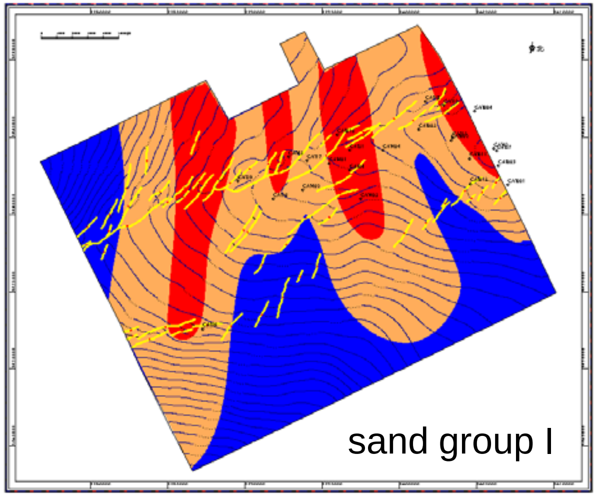
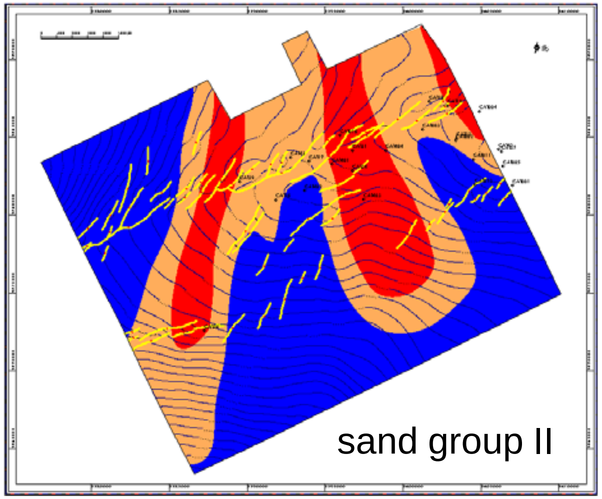
Notes by Presenter: Reservoir prediction in the region of study, choose a representative of the amplitude of the frequency tuning area to describe the spatial variation of the reservoir, that is used 30,40, 50Hz tuning frequency corresponding to describe the amplitude of the horizontal reservoir distribution rules.

# APPLICATION EXAMPLES

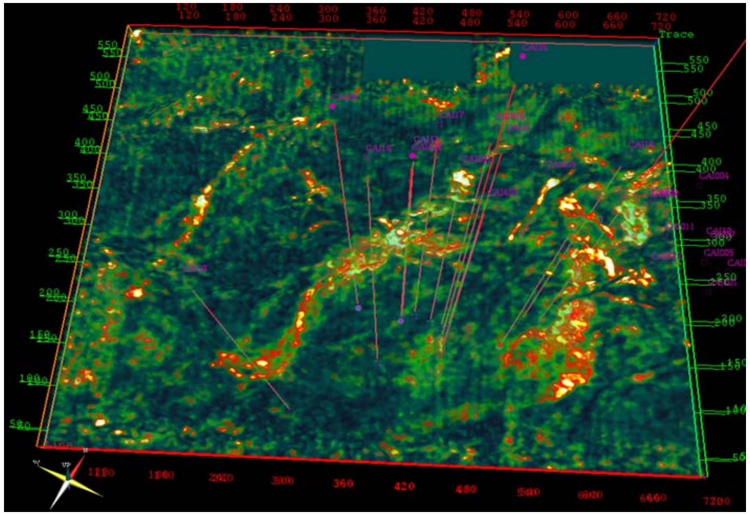
## a、 Identifing Channels

### Sedimentary Facies Plan in the $J_1s_2$

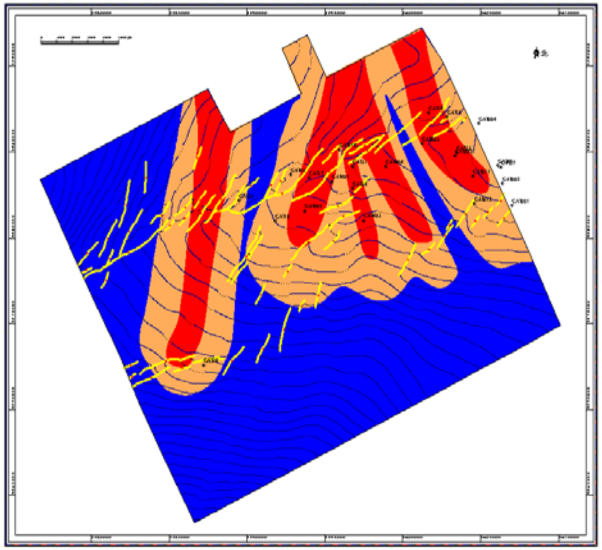

sand group I


sand group II

$J_1s_2$ is delta front deposits, source from north and is mainly underwater distributary channel sediments composed of gray sandstone, fine sandstone in the thickness range of 8~25m.



The amplitude plan of spectrum decomposition in $J_1s_2$



Sedimentary Facies Plan in the $J_2x$

# OUTLINE

- **BASIC PRINCIPLE**
- **APPLICATION EXAMPLES**

  a、 Identifing Channels

  b、 Identifing Stratigraphic Trap

  E.g. South of XY 2 Well 3-D Work Area

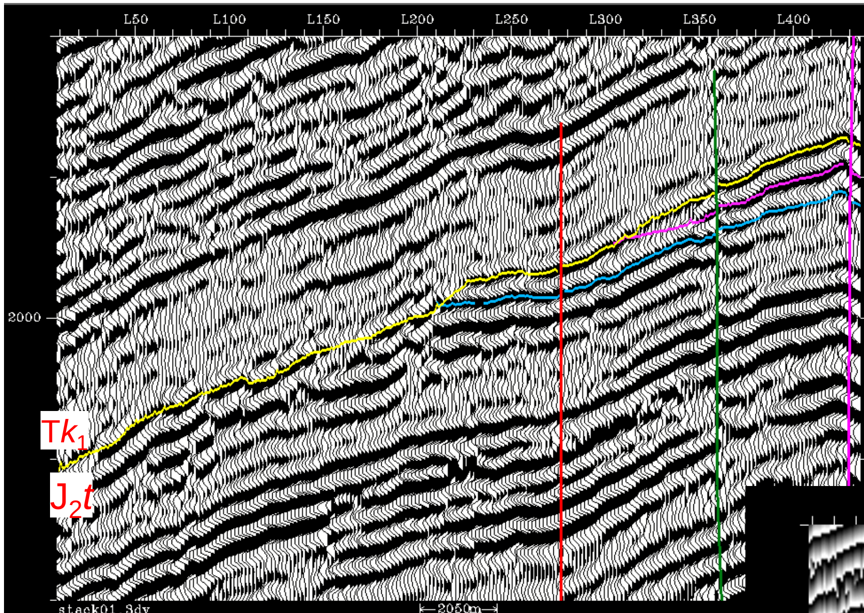
  c、 Identifing Lithologic Trap
- **CONCLUSIONS**



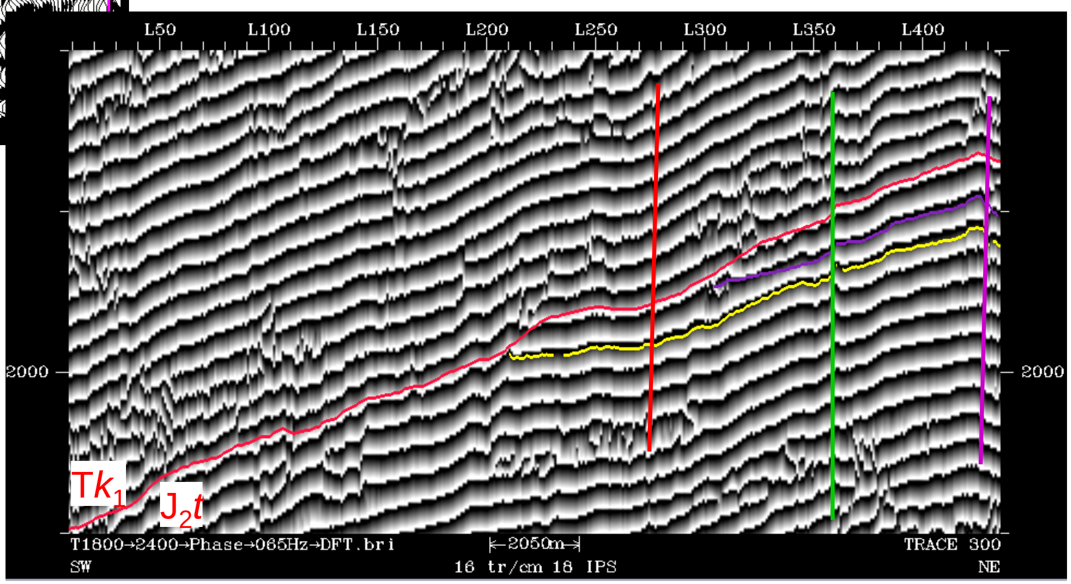


# APPLICATION EXAMPLES

## b、 Identifing Stratigraphic Trap

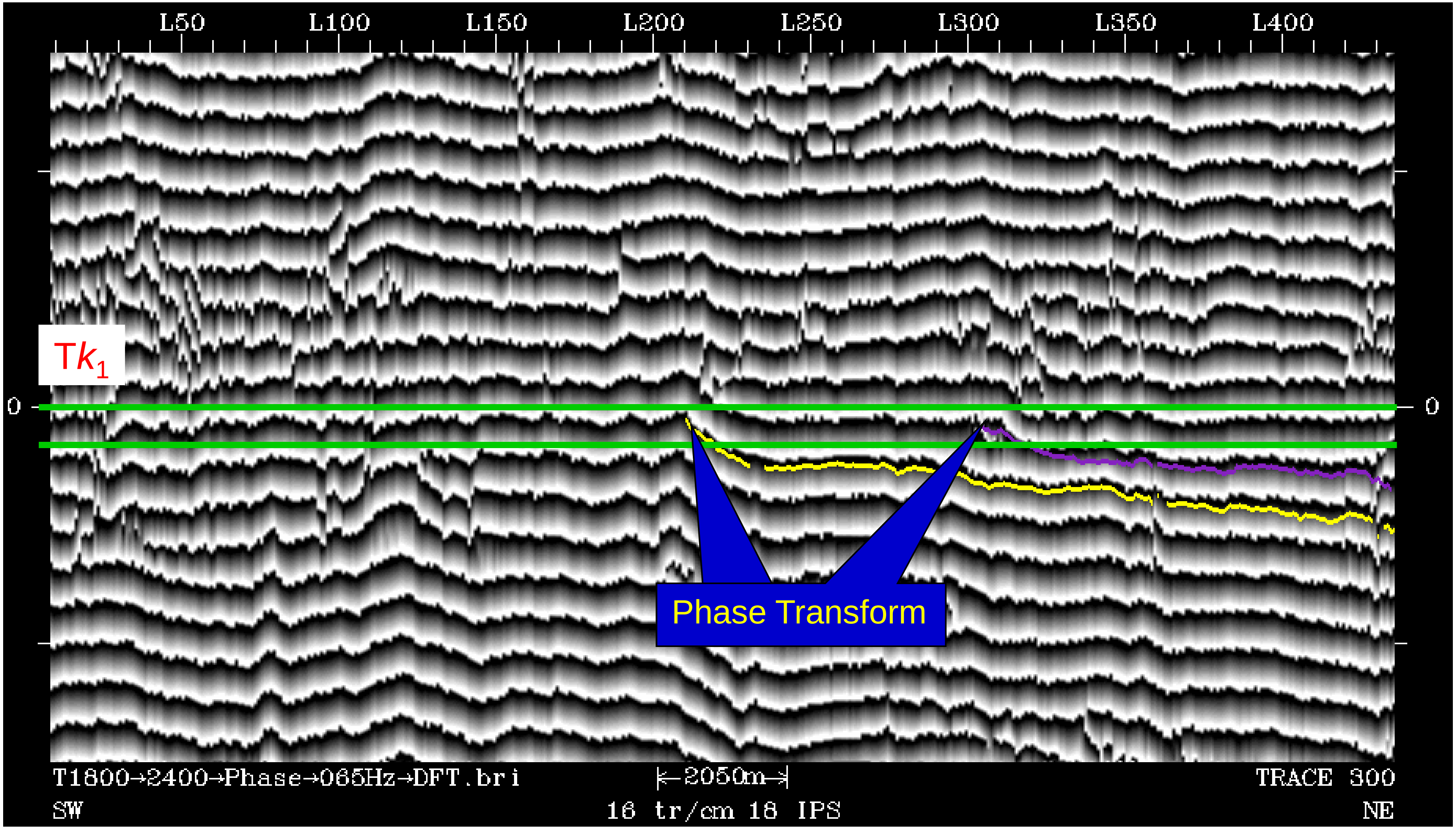



**Trace300 Seismic Section**



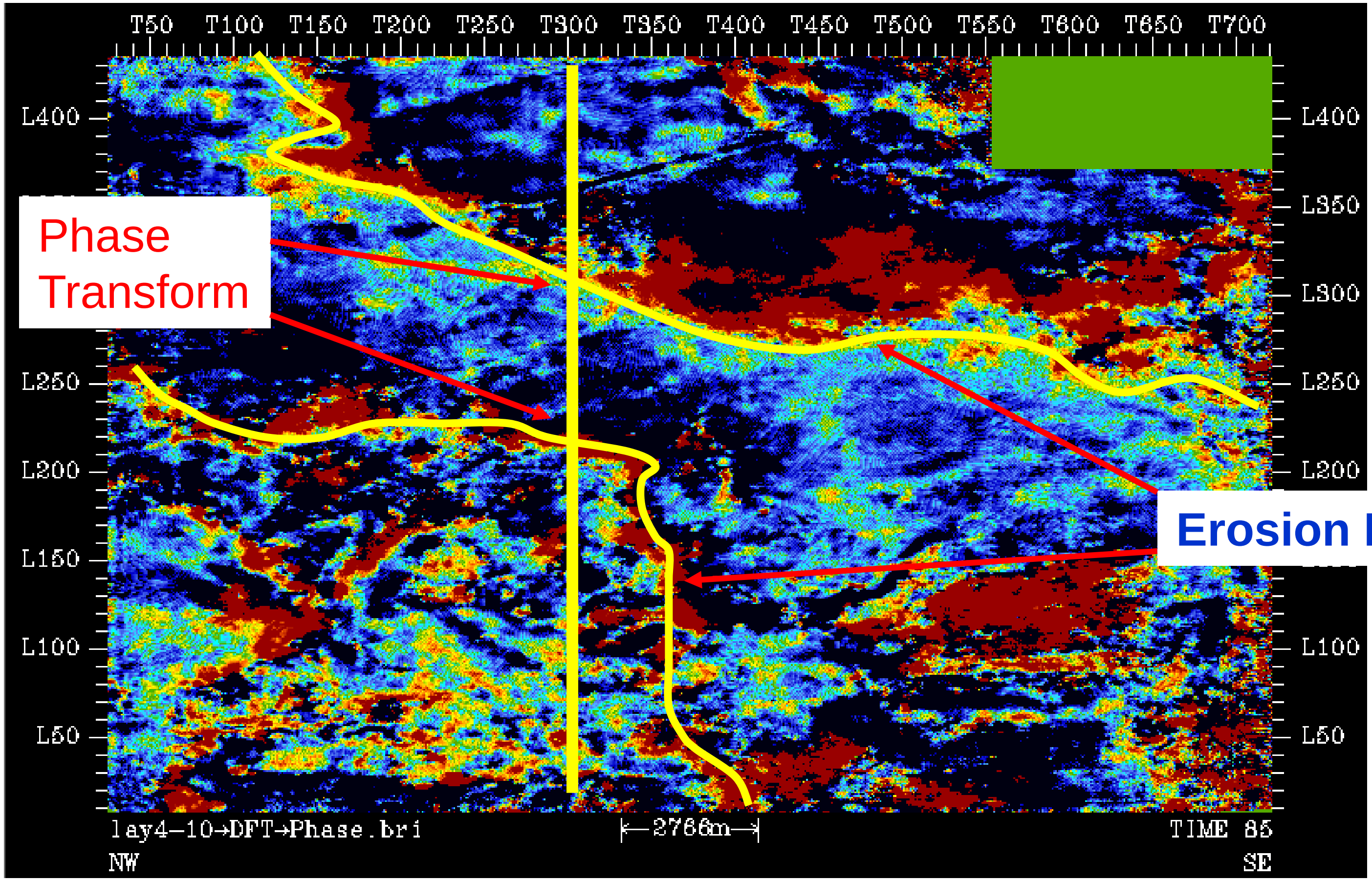

**Trace300 Spectral decomposition phase spectrum section**

◆Trace300 Spectral decomposition phase spectrum section(along $Tk_1$ after flattening )



## b、 Identifing Stratigraphic Trap

◆After analysing of the phase plan of the bottom of the Cretaceous($Tk_1$) , choosing a higher frequency of phase plan to determine the erosion line.

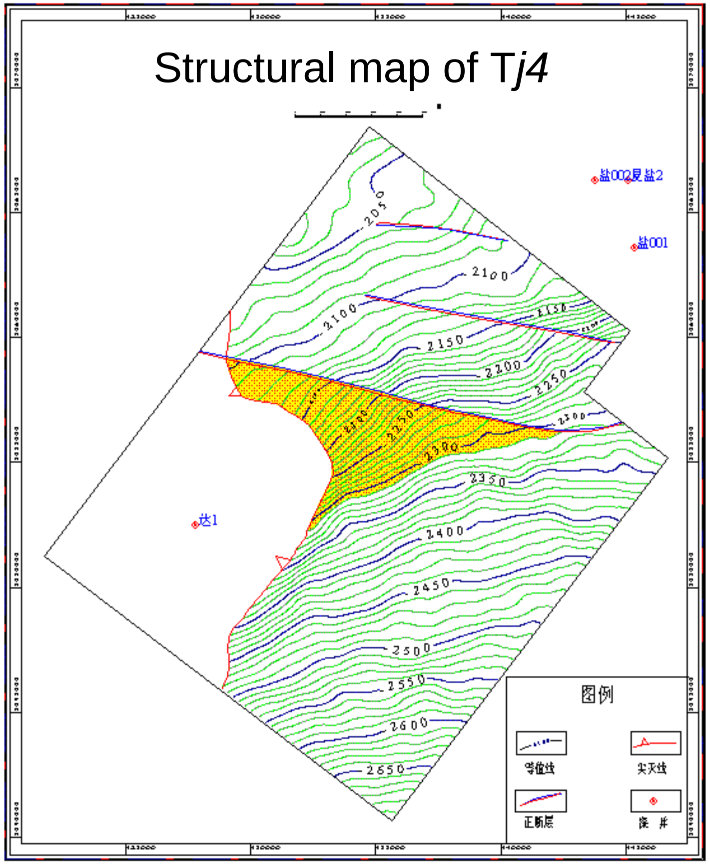


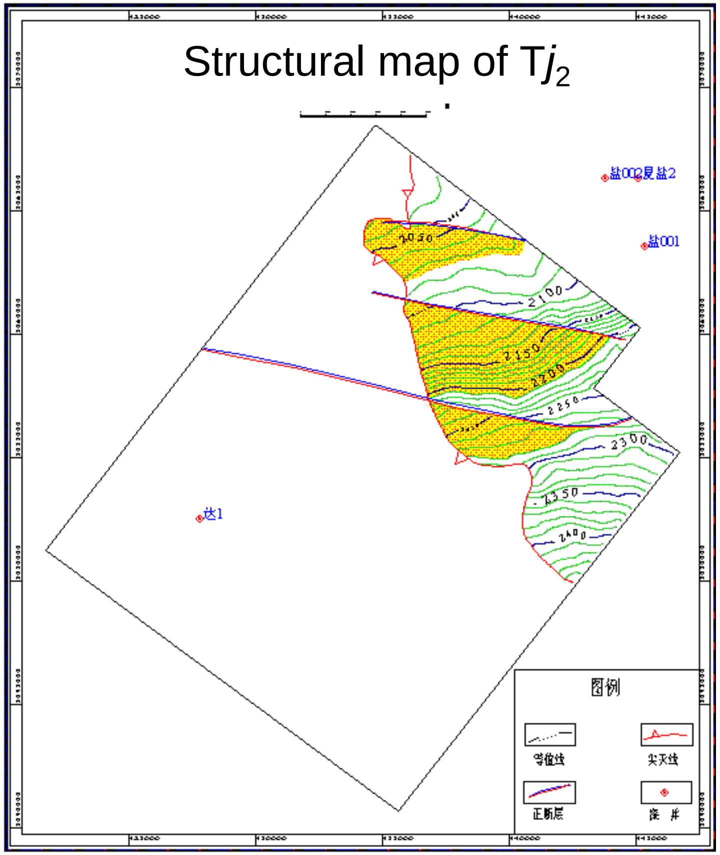

**Spectral decomposition phase plan (85Hz)**

APPLICATION EXAMPLES

b、 Identifing Stratigraphic Trap

## ◆Faults-Stratigraphic Trap of Toutonghe Formation($J_2t$)



# OUTLINE

- **BASIC PRINCIPLE**
- **APPLICATION EXAMPLES**

  a、 Identifing Channels

  b、 Identifing Stratigraphic Trap

  c、 Identifing Lithologic Trap

  E.g. SN 31 Well 3-D Work Area
- **CONCLUSIONS**

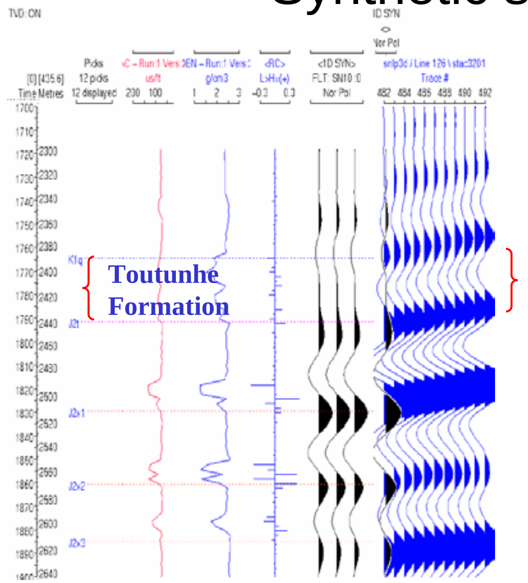
# APPLICATION EXAMPLES

## c、 Identifing Lithologic Trap

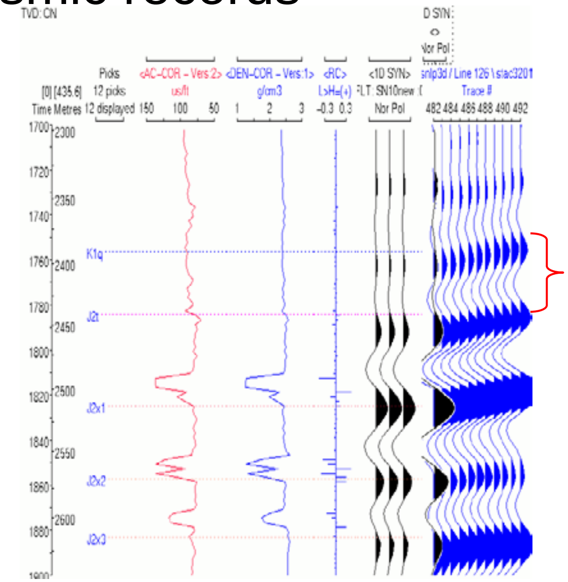
◆Logging environmental correction

◆Standardized processing

Synthetic seismic records

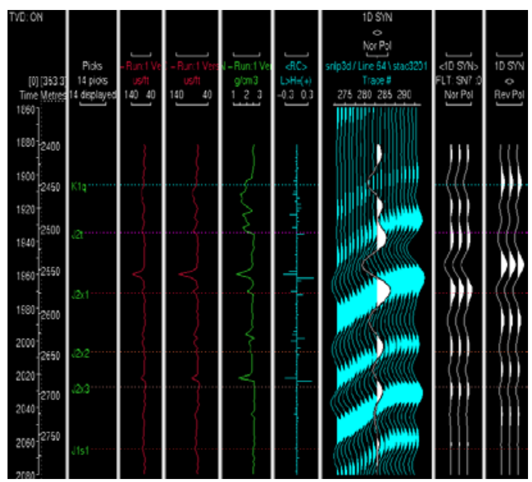



Before

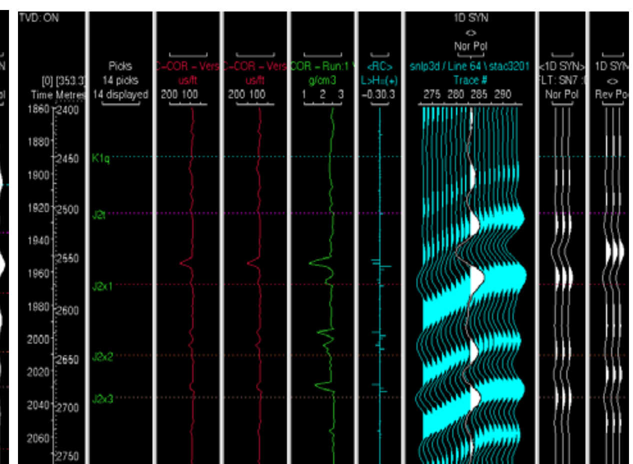


After

Before: hard to compare
After: good to compare



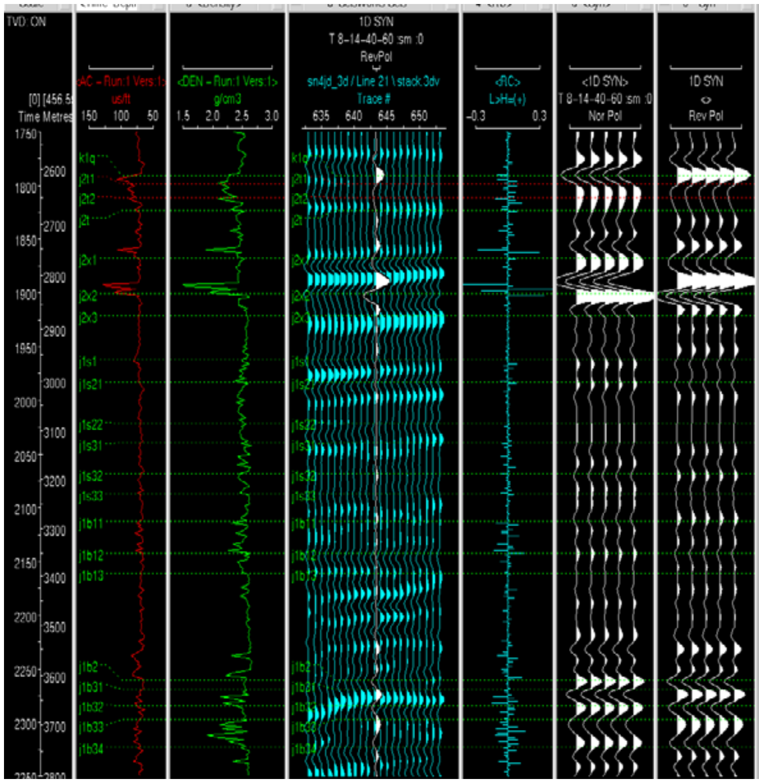
Before



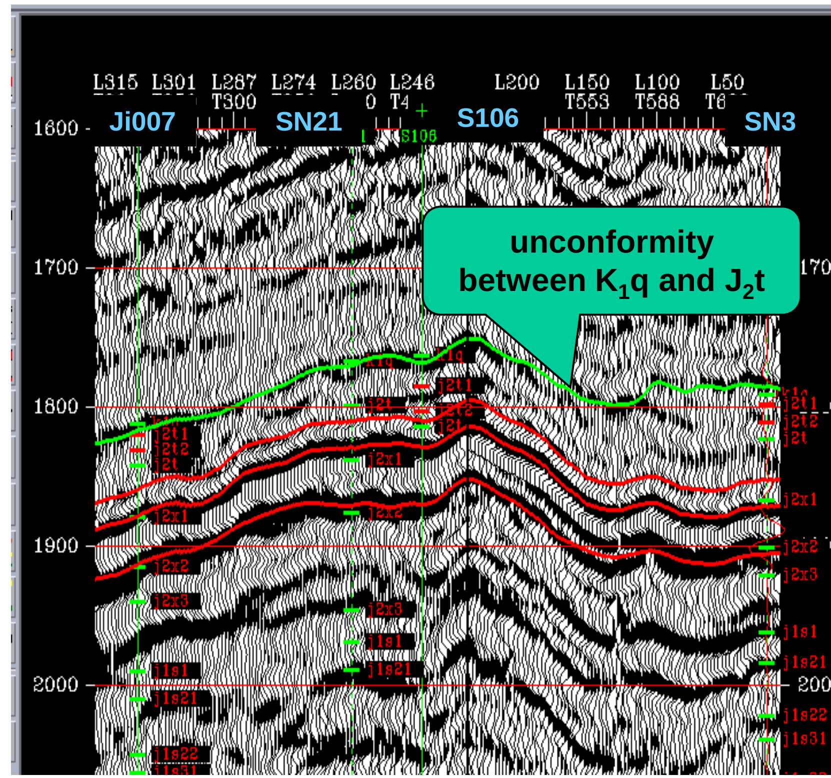
After

# APPLICATION EXAMPLES

## c、 Identifing Lithologic Trap

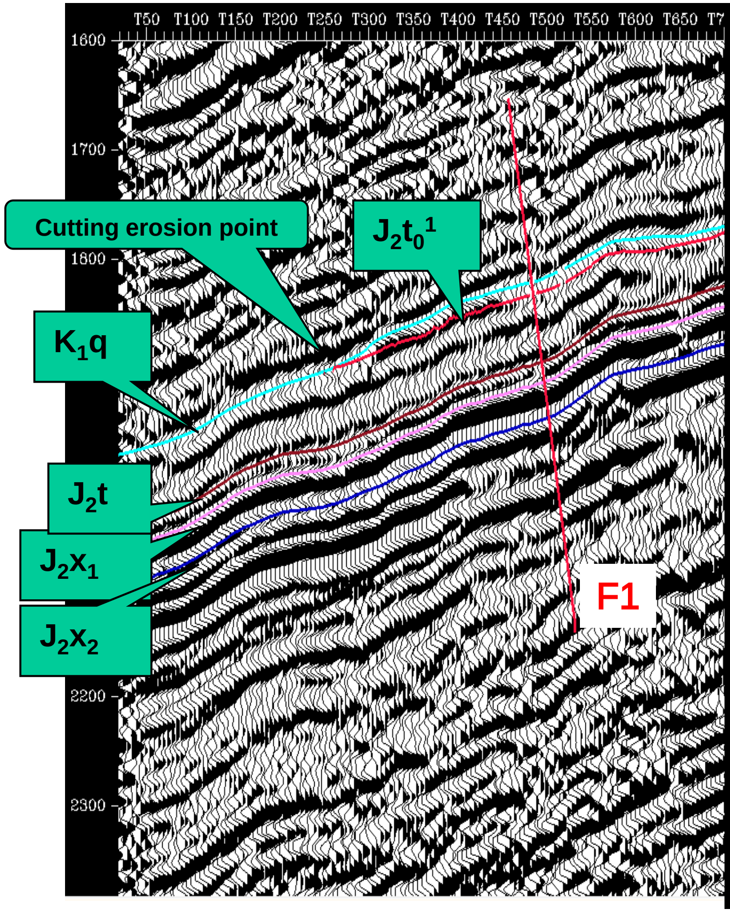


SN3 well horizon calibration

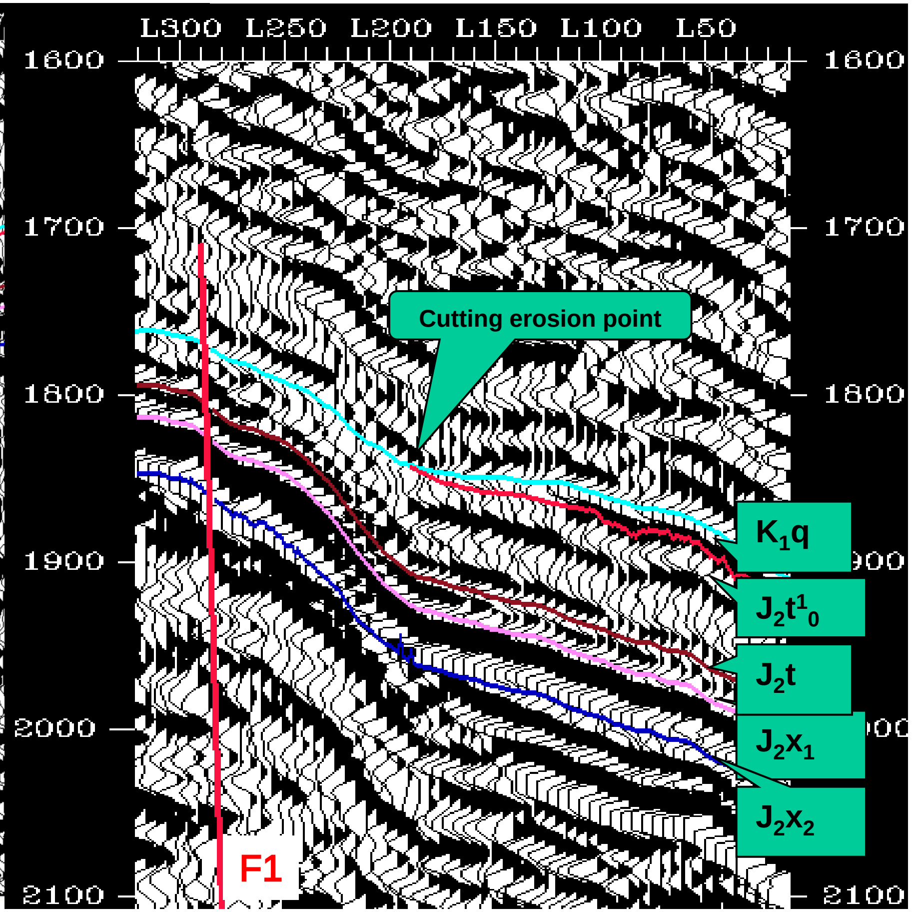



Joint wells section

## ◆Lithologic trap identification



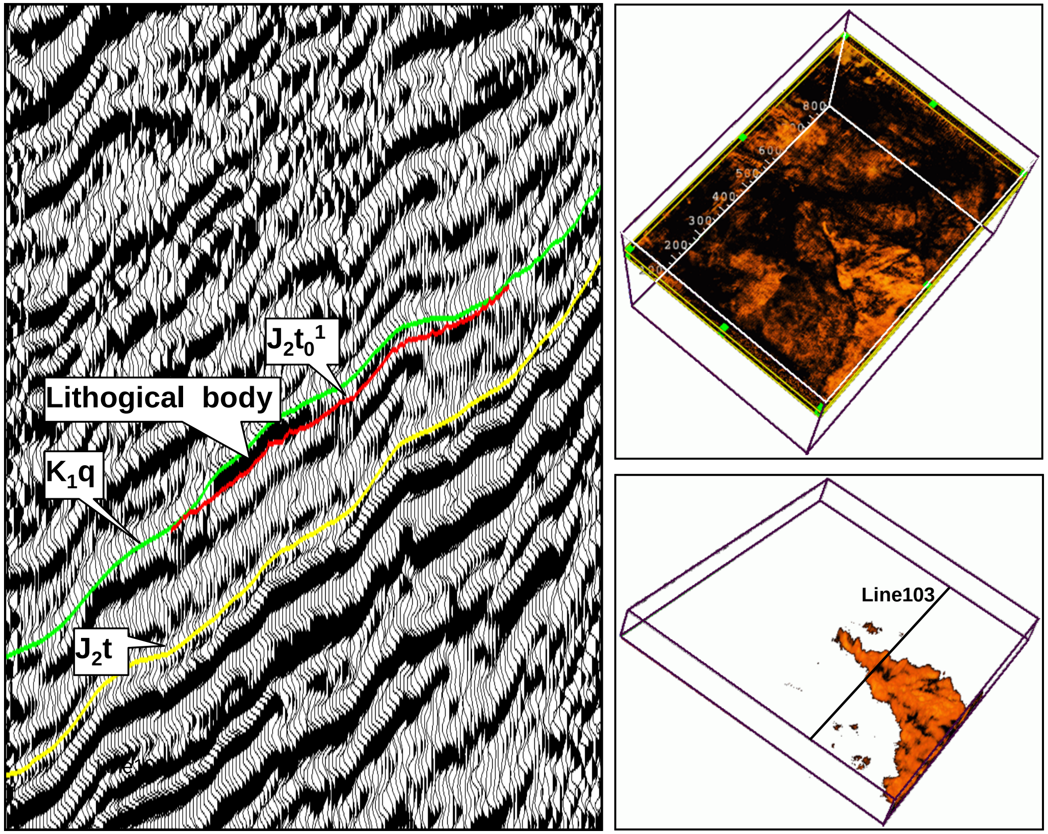

Line100




XLine 350

# APPLICATION EXAMPLES

## c、 Identifing Lithologic Trap




**Left:** Line103 seismic section (Phase shift 90º) **Right:** Full 3-D visualization plan

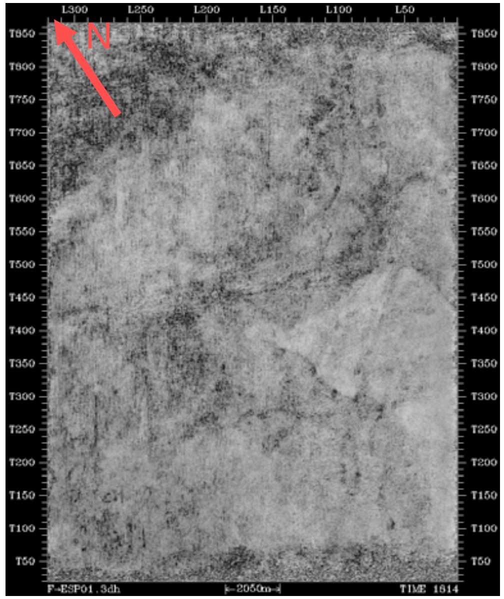
**Top right:** Along $Tk_1$ after flattening down 0-38ms perspective results

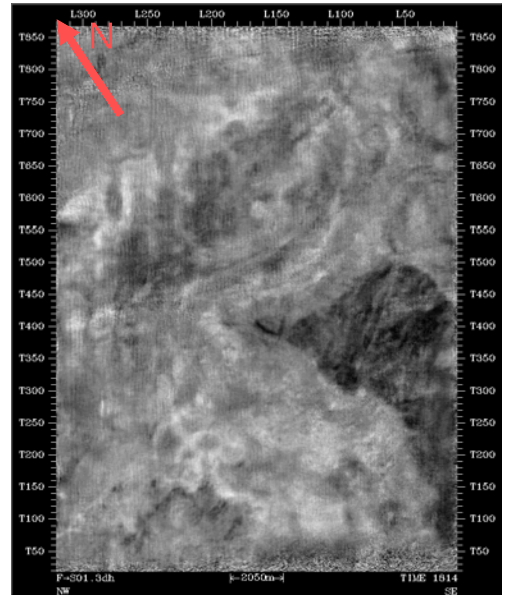
**Bottom right:** Along $Tk_1$ after flattening down 0-16ms perspective results

# APPLICATION EXAMPLES

## c、 Identifing Lithologic Trap

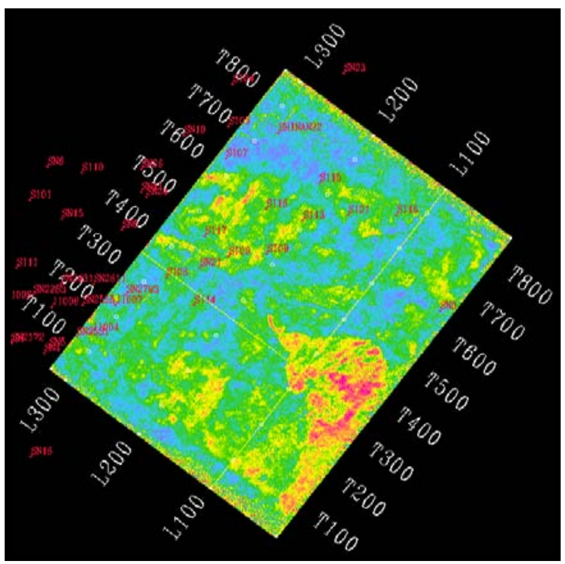
**Coherence time slices** (along T$k_1$ after flattening down 14ms)

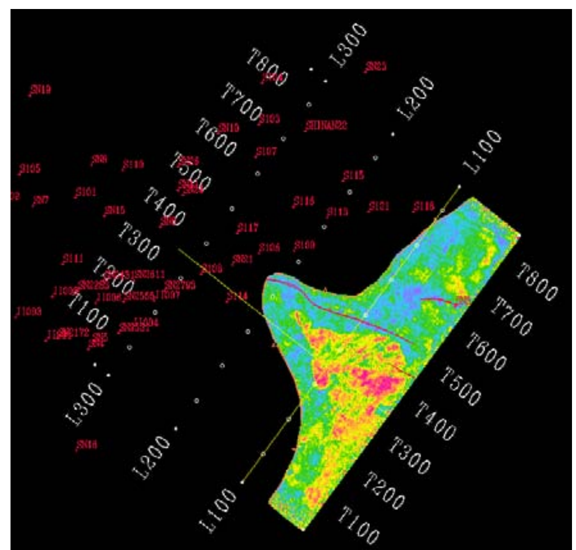



**Time slices** (along T$k_1$ after flattening down 14ms)

**RMS amplitude Plan**( along T$k_1$ down 0-30ms)

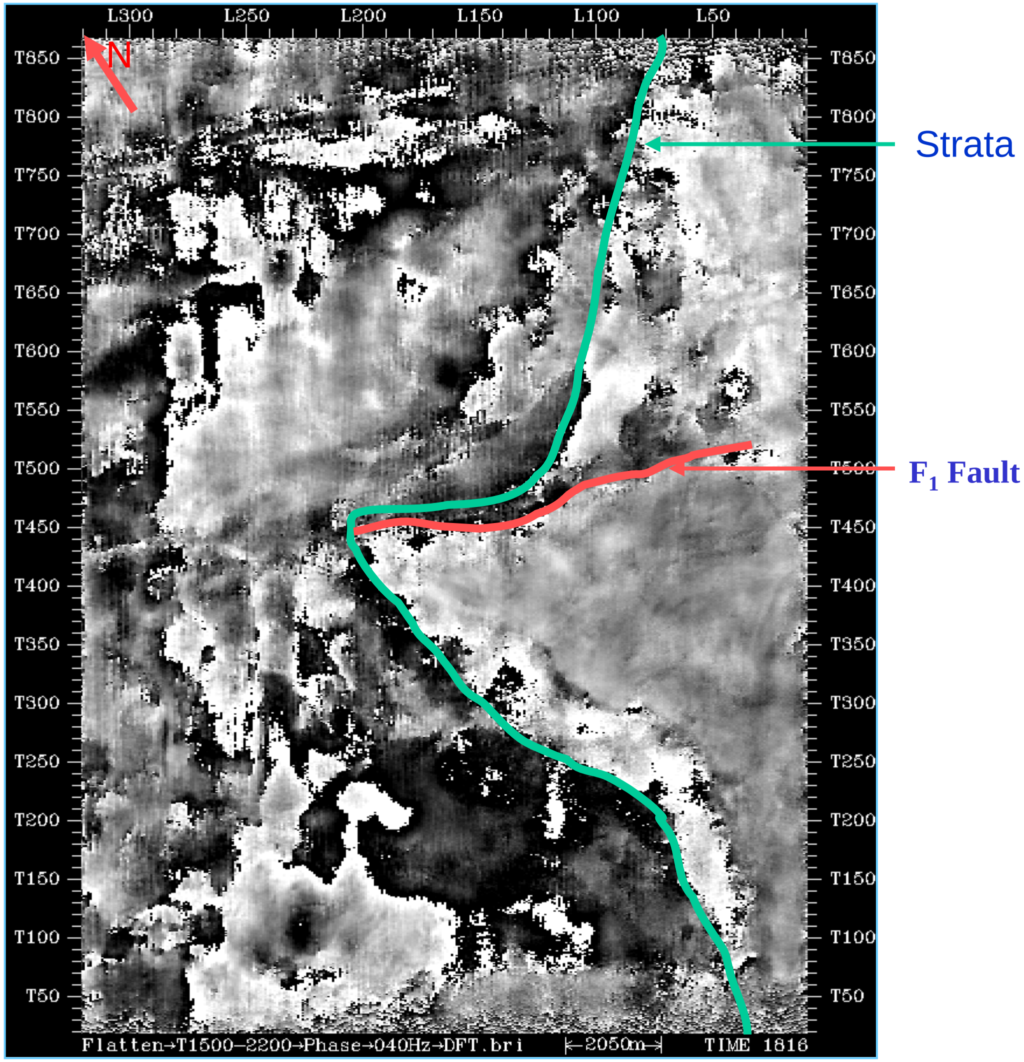



**RMS amplitude Plan**( along $J_2t_0^1$ both up and down 15ms)

## c、 Identifing Lithologic Trap

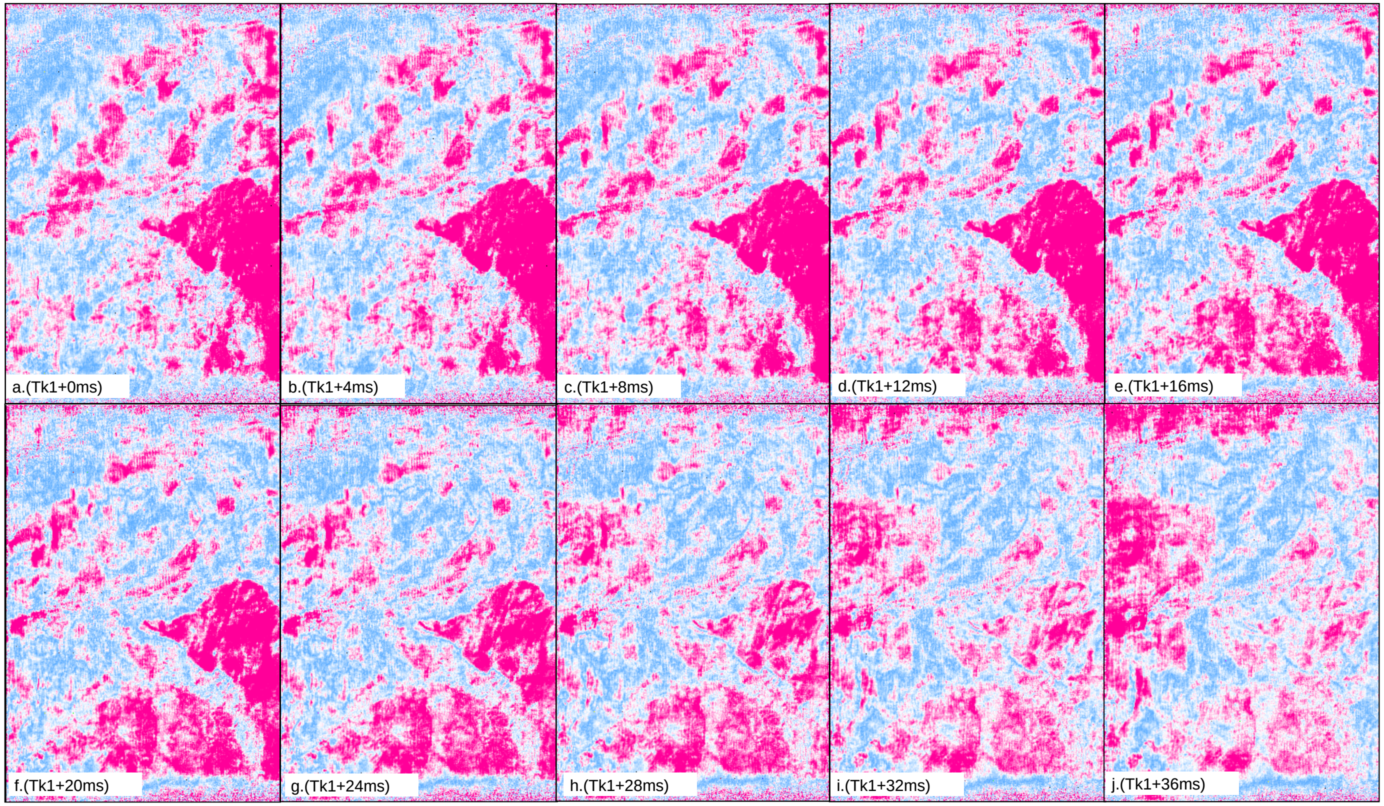
◆ Spectral decomposition Phase slice (40Hz,along $Tk_1$ after flattening down 16ms)



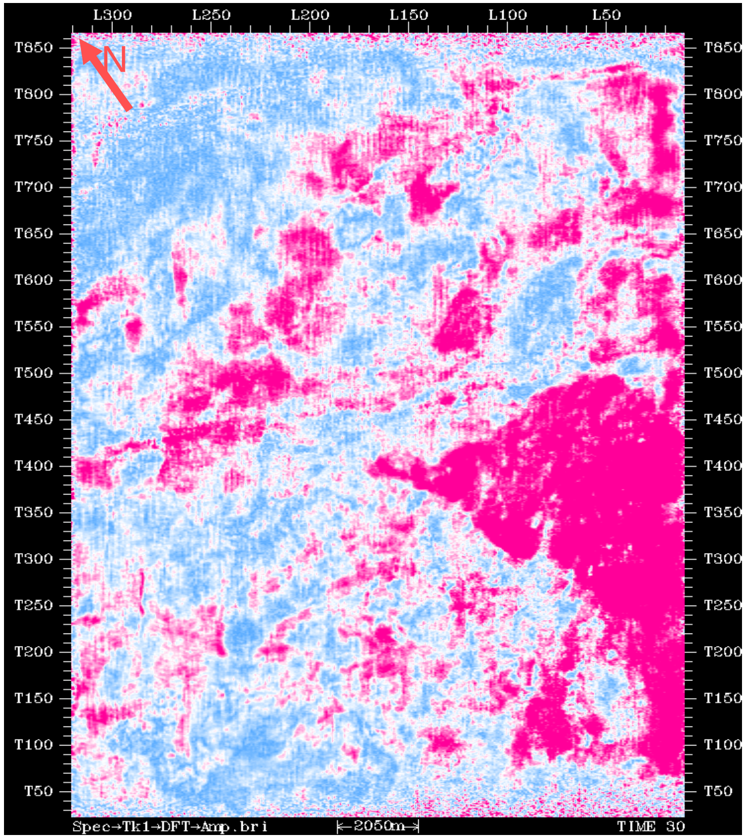

***The phase spectrum can be utilized to indicate the lateral discontinuity of geologic bodies！***

## c、 Identifing Lithologic Trap

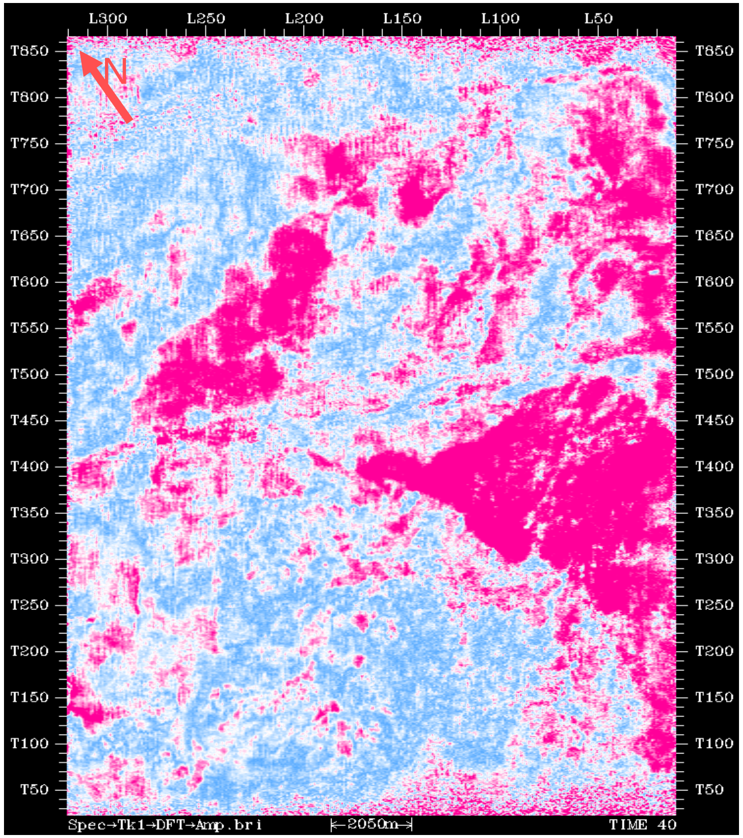
- Spectral decomposition amplitude spectrum Slice (along $Tk_1$ after flattening down 0-50ms，30Hz)



## ◆ Spectral decomposition amplitude plan (along T$k_1$)




30Hz

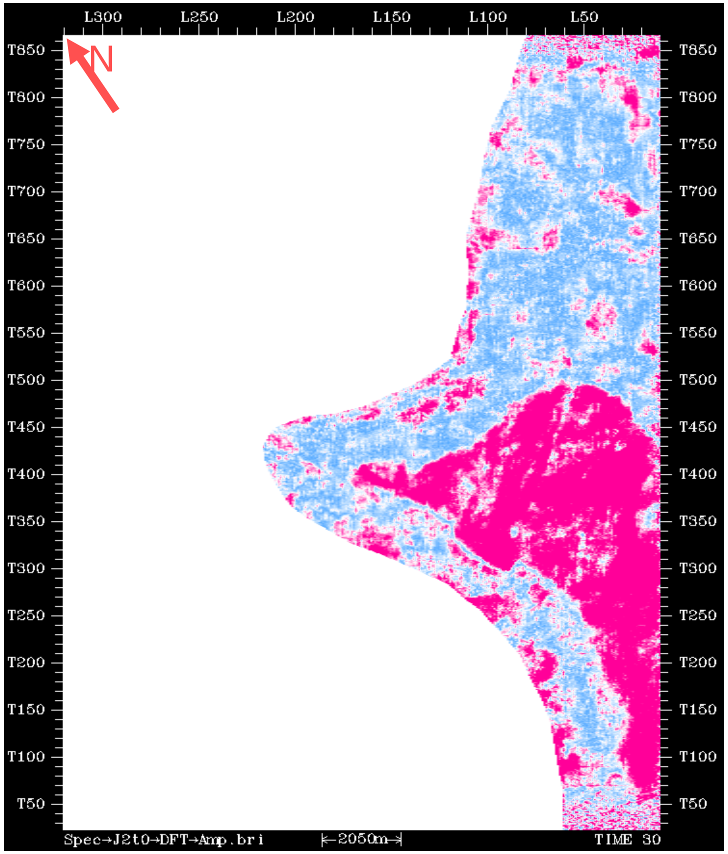


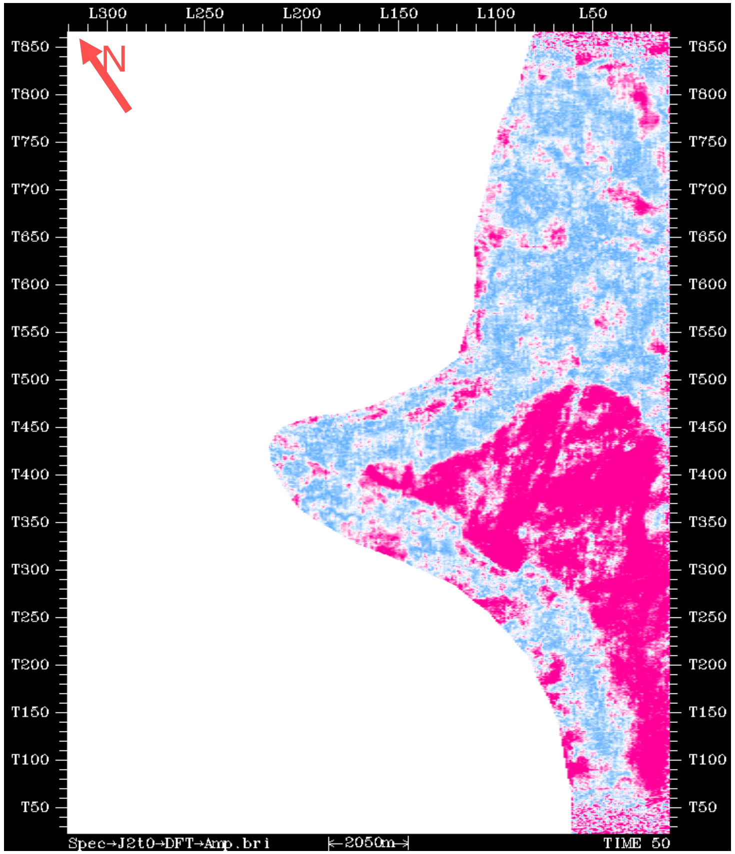

40Hz

APPLICATION EXAMPLES

c、 Identifing Lithologic Trap

## ◆ Spectral decomposition amplitude plan (along $J_2t_0^1$ )

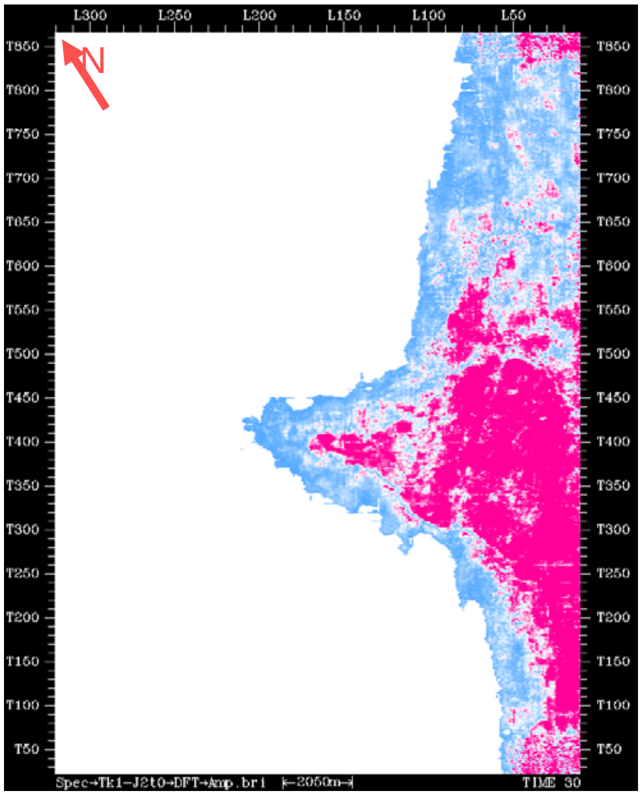


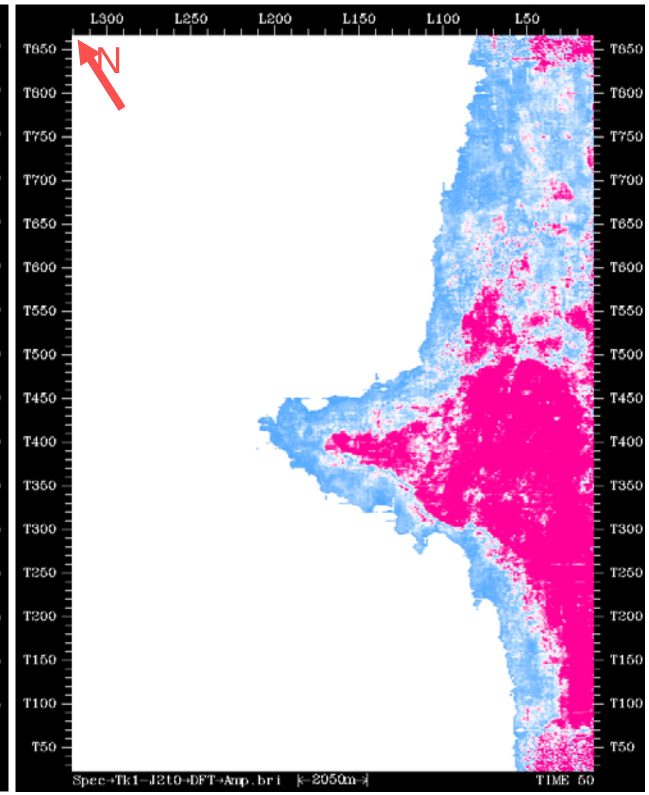

30Hz

50Hz

- Spectral decomposition amplitude plan (between T$k_1$ and $J_2 t_0^1$ )




30Hz



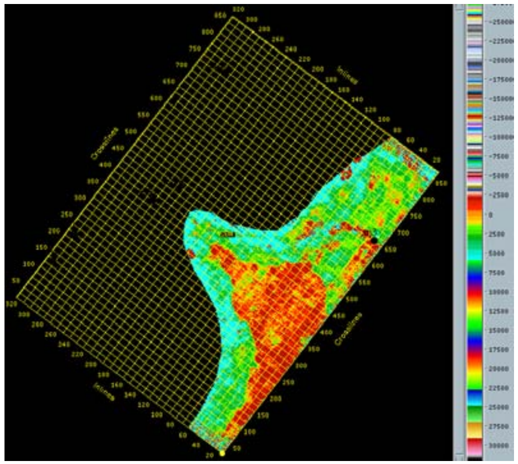

50Hz

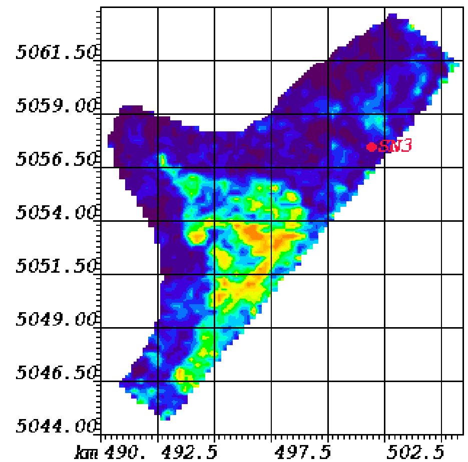
# APPLICATION EXAMPLES

## c、 Identifing Lithologic Trap

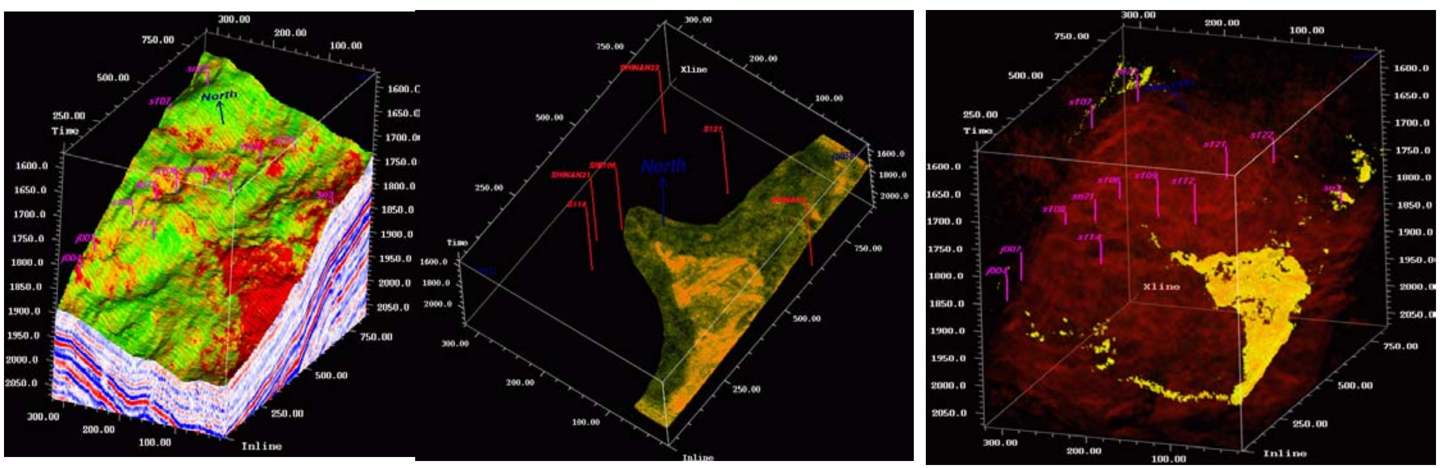
### ◆Seismic Facies Analysis and 3-D Visualization

Seismic Facies
(along $J_2t_0^1$ up 0-15 ms)





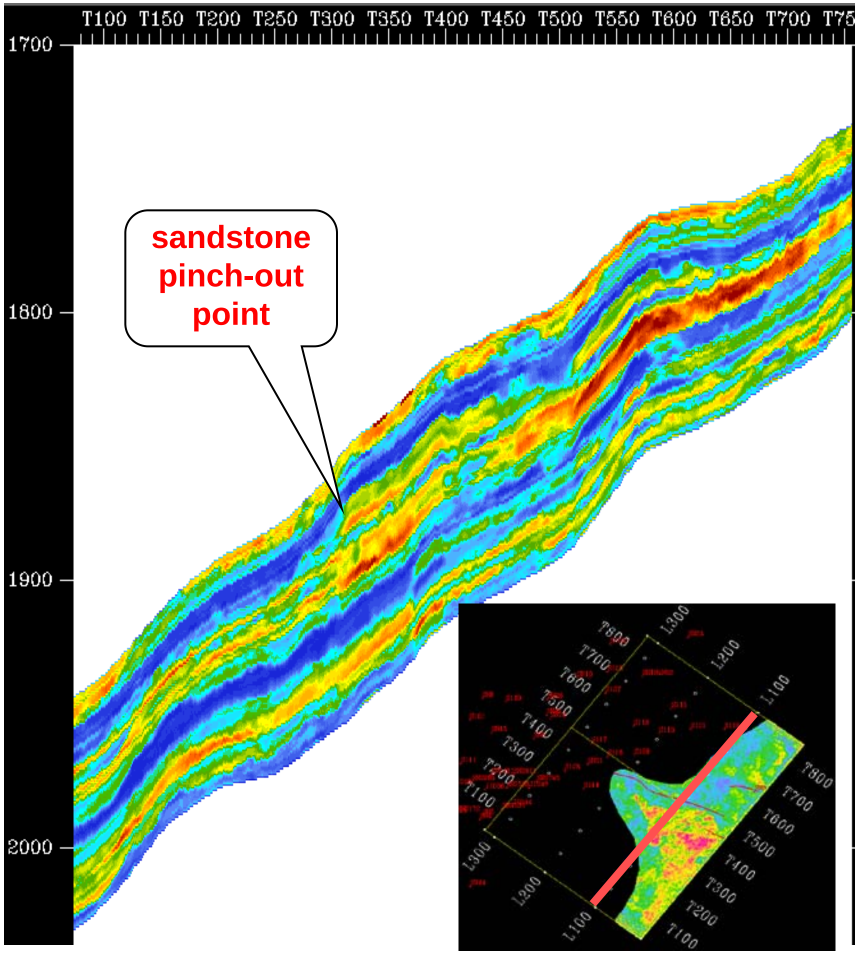

Average energy plan
(along $J_2t_0^1$)



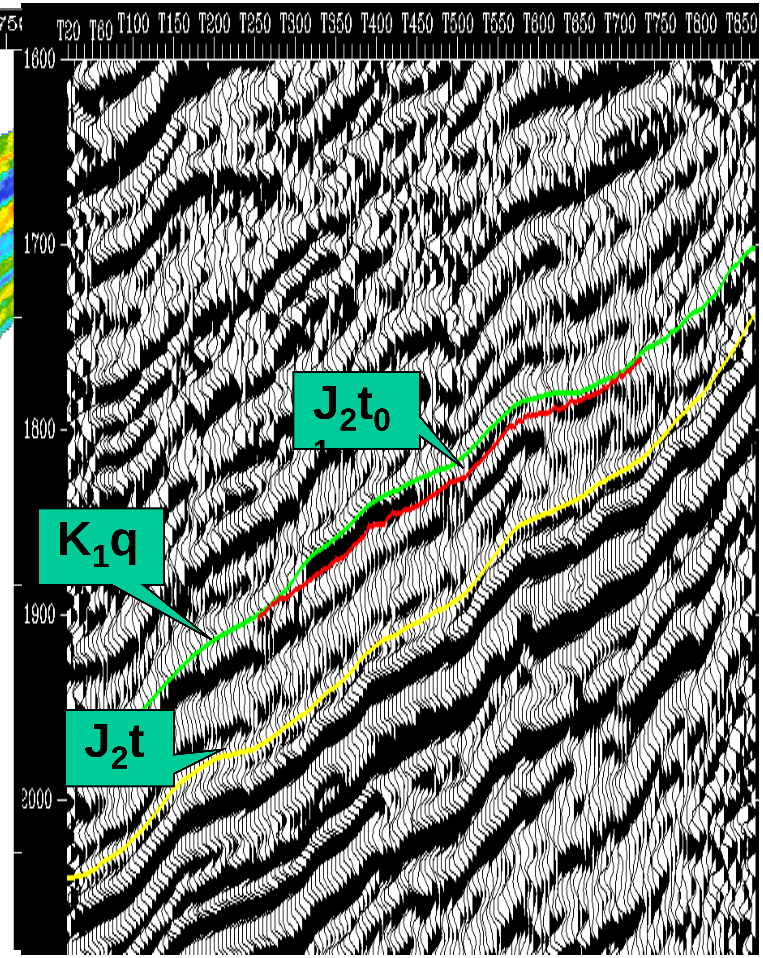
3-D visualization (along $J_2t_0^1$)

# APPLICATION EXAMPLES

## c、 Identifing Lithologic Trap



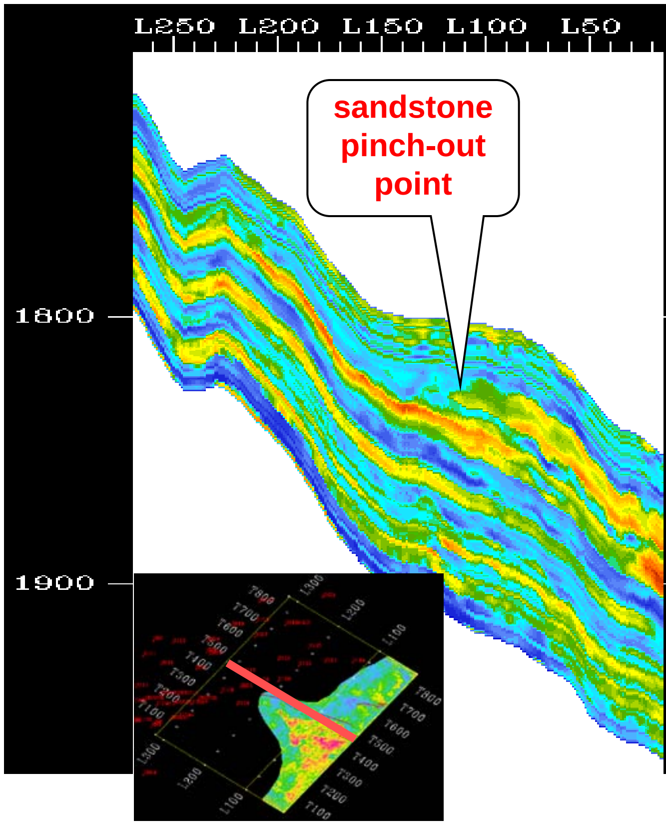

Line103 Gamma inversion Section

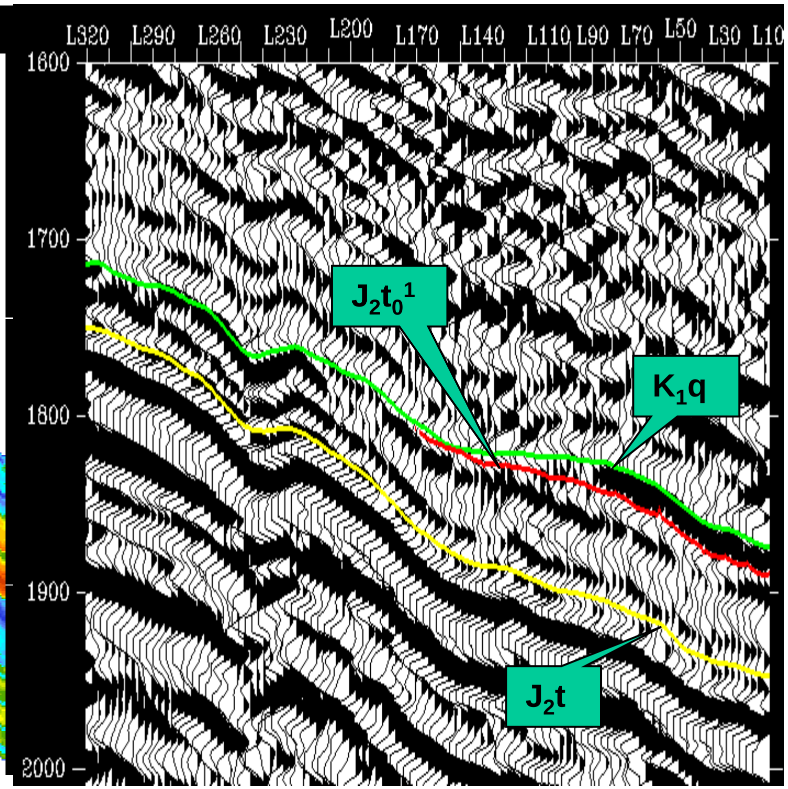



Line103 Seismic Section
(Phase shift 90º)

# APPLICATION EXAMPLES

## c、 Identifing Lithologic Trap

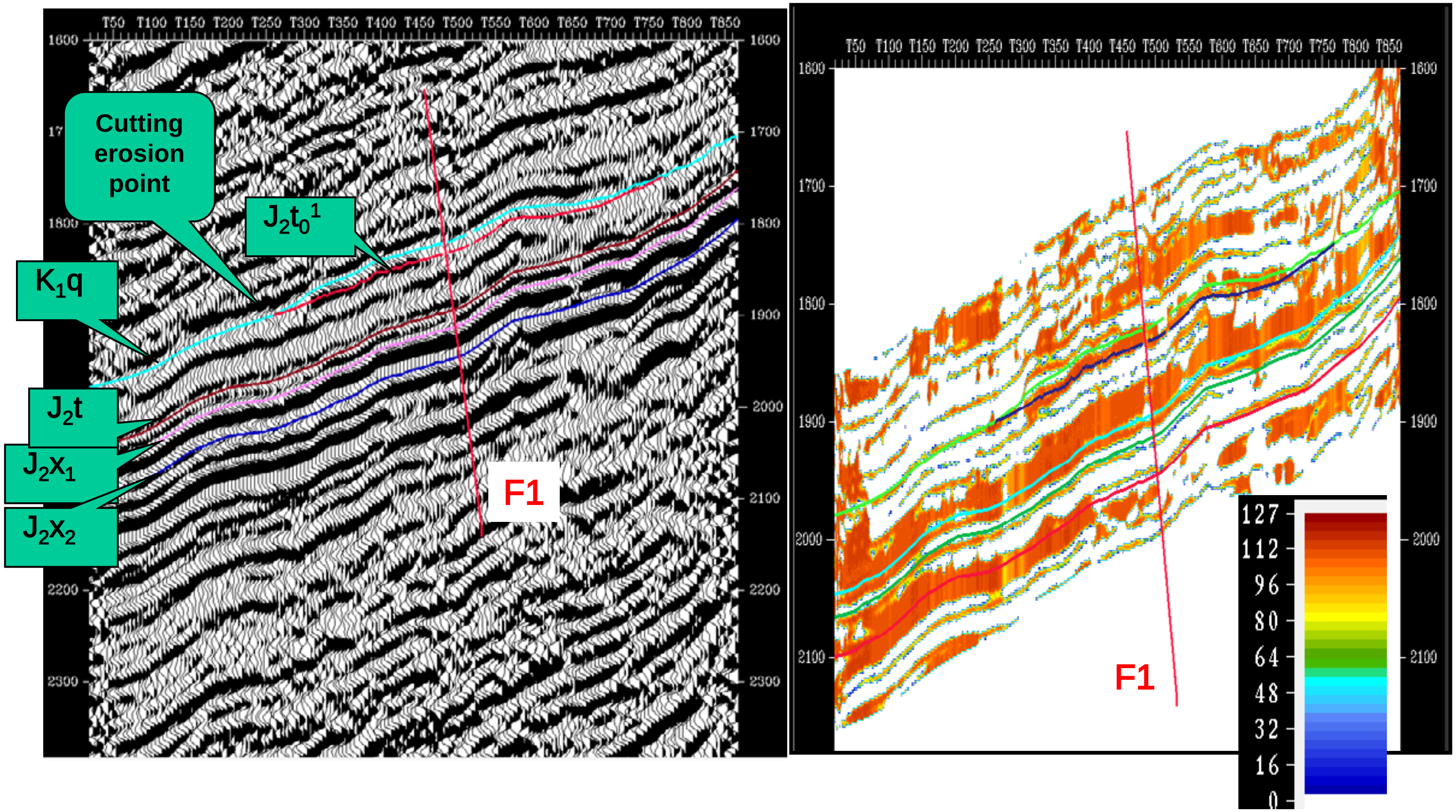



**Trace468 Gamma inversion Section**

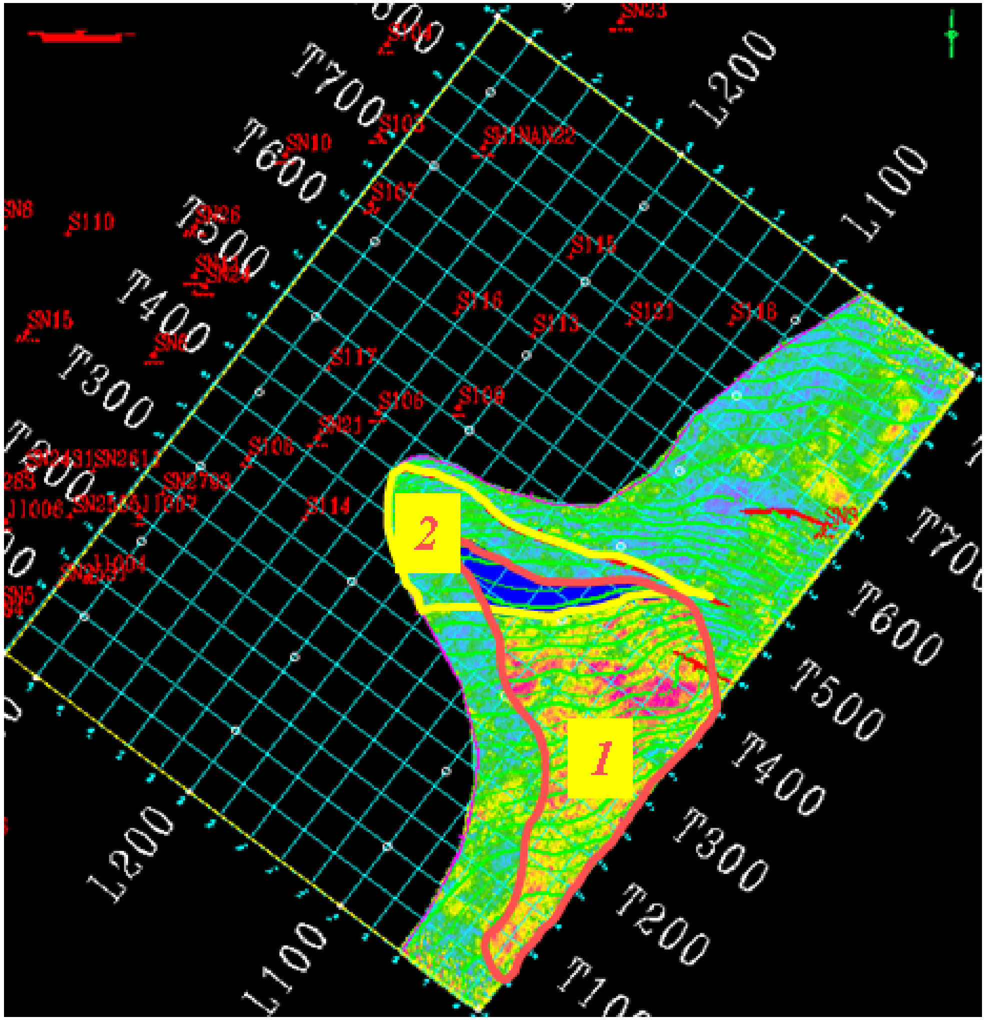
**Trace468 Seismic Section (Phase shift 90º)**

## c、 Identifing Lithologic Trap




**Line100 Absorption Coefficient Section**

## c、 Identifing Lithologic Trap



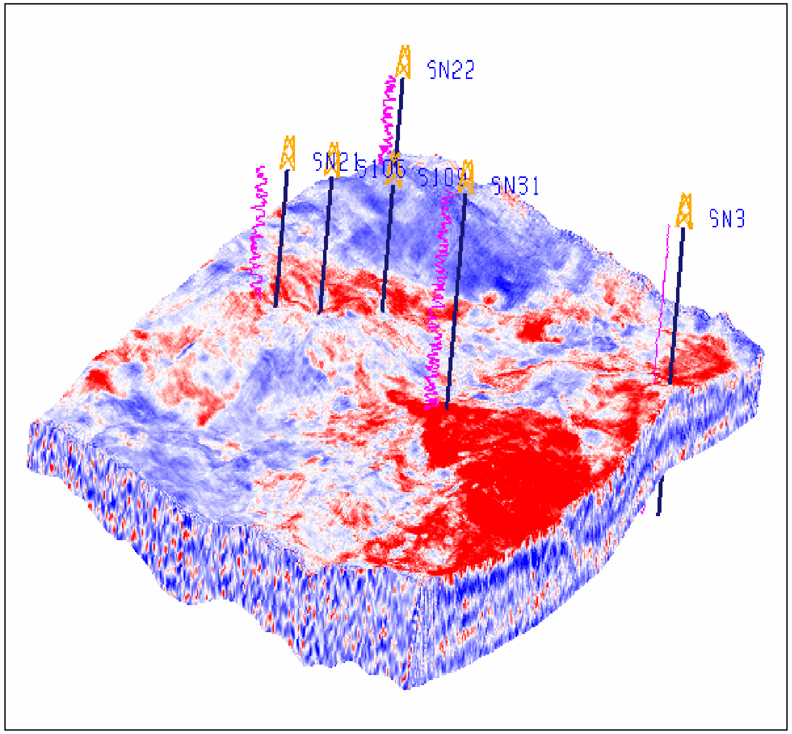

About Lithologic Traps

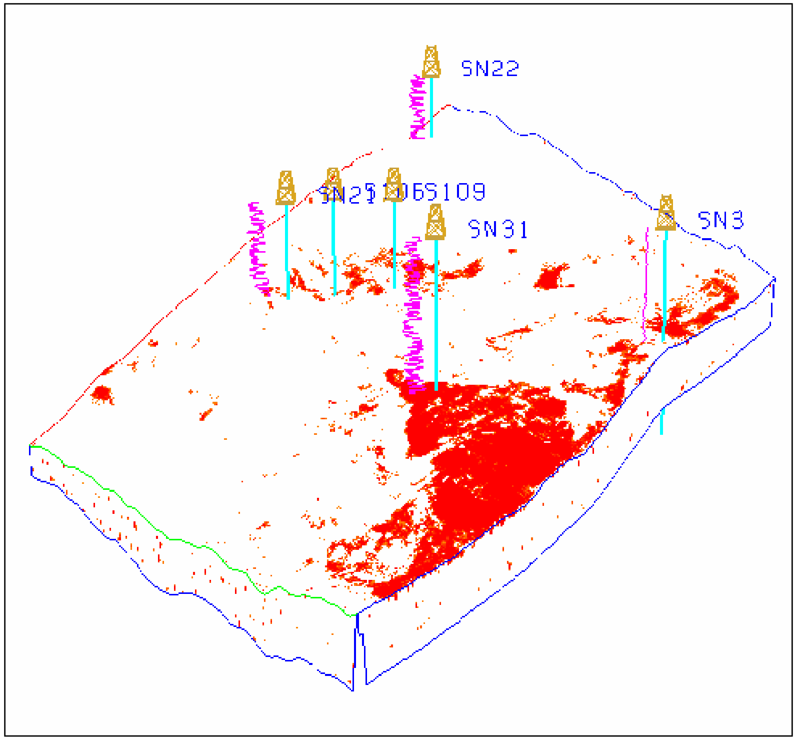
◆Because of the source come from the northeast, we believe that lithology of trap 1 is sandstone.

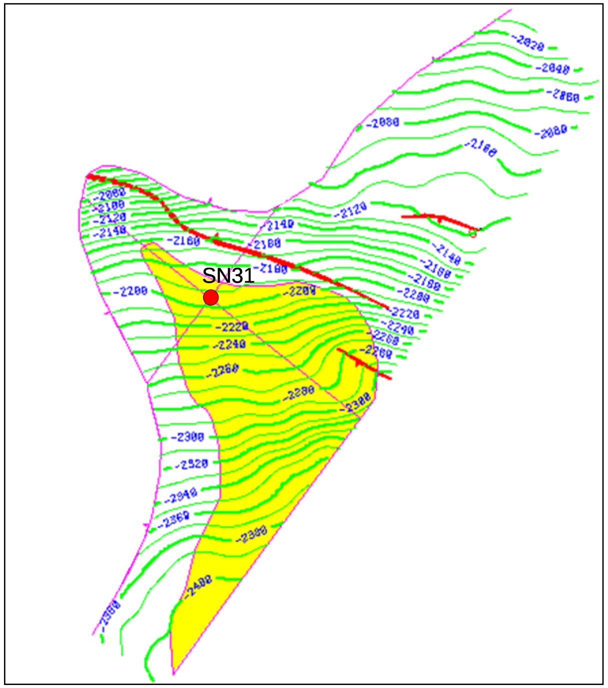
◆Fault-Stratigraphic trap 2 is mudstone.

Trap 1 is a effective trap
Trap 1 Area: 35km$^2$
Closed range : 230m

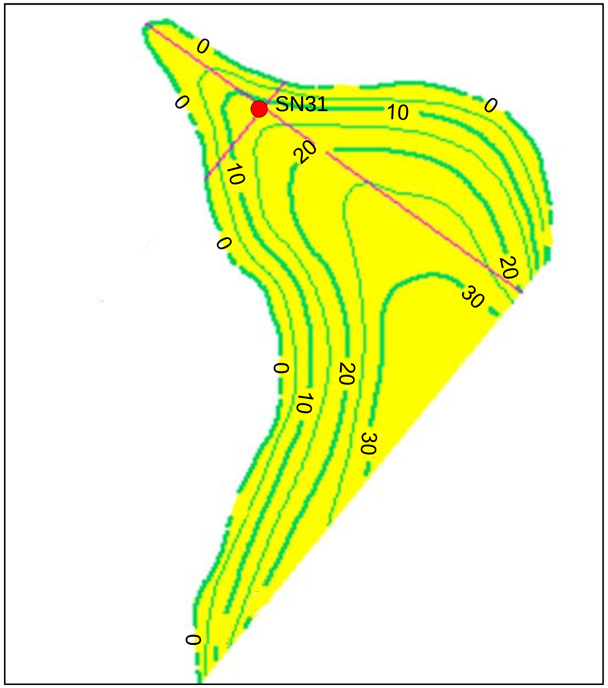
◆3-D visualization of Impedance inversion data volume **(between $Tk_1$ and $J_2t_0^1$)**






**Structural map of top of Lithologic Trap**




**Thickness map of Lithologic Trap**

## Precision Analysis

① Top of the Trap: Predict the depth of 2620m, real drilling is 2606m, the absolute error is 14m, the relative error is 5‰ .

② Sandstone thickness prediction 12m, real drilling is 13.2m, the absolute error is 1.2m.

# APPLICATION EXAMPLES

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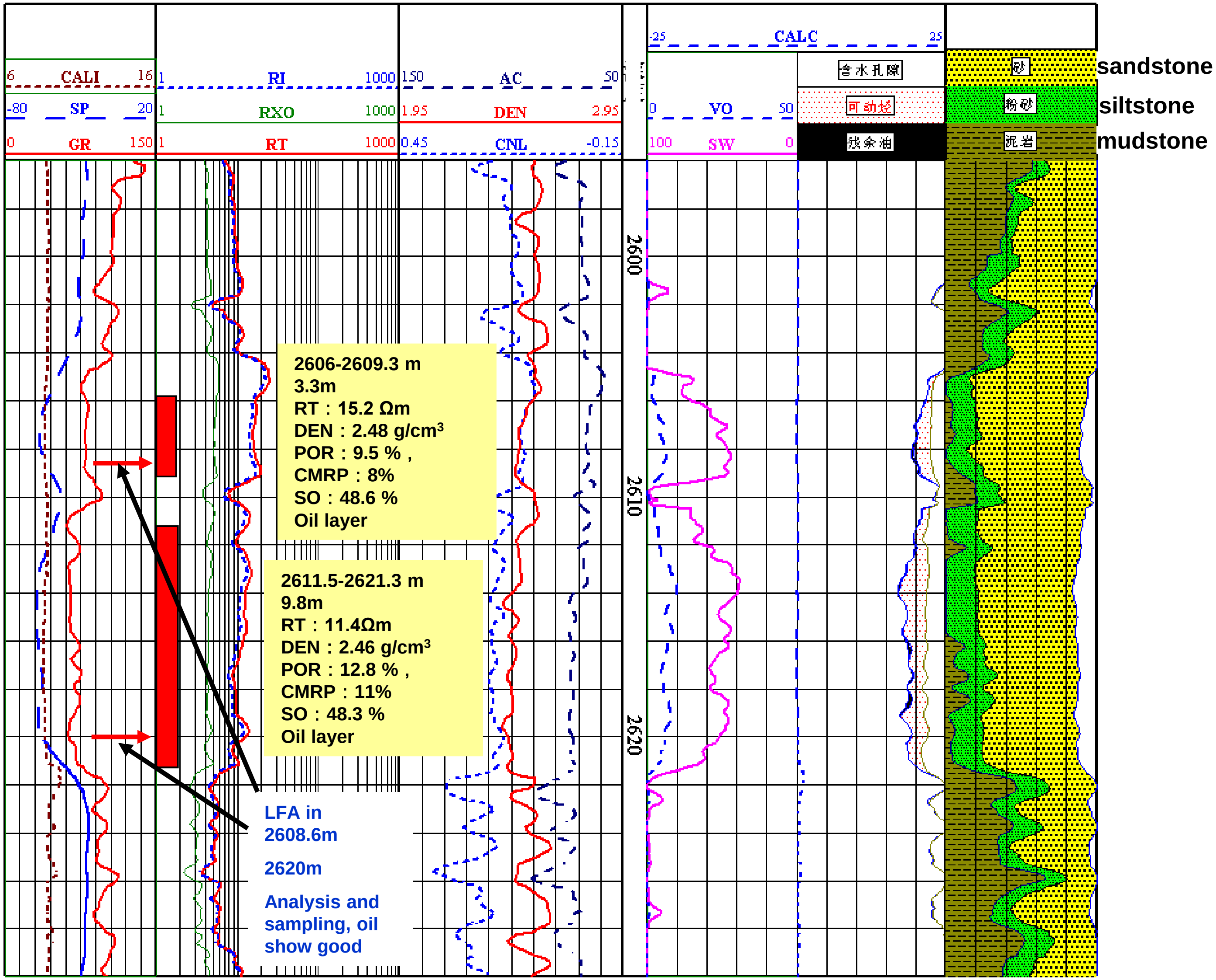


**SN 31 well logging interpretation**

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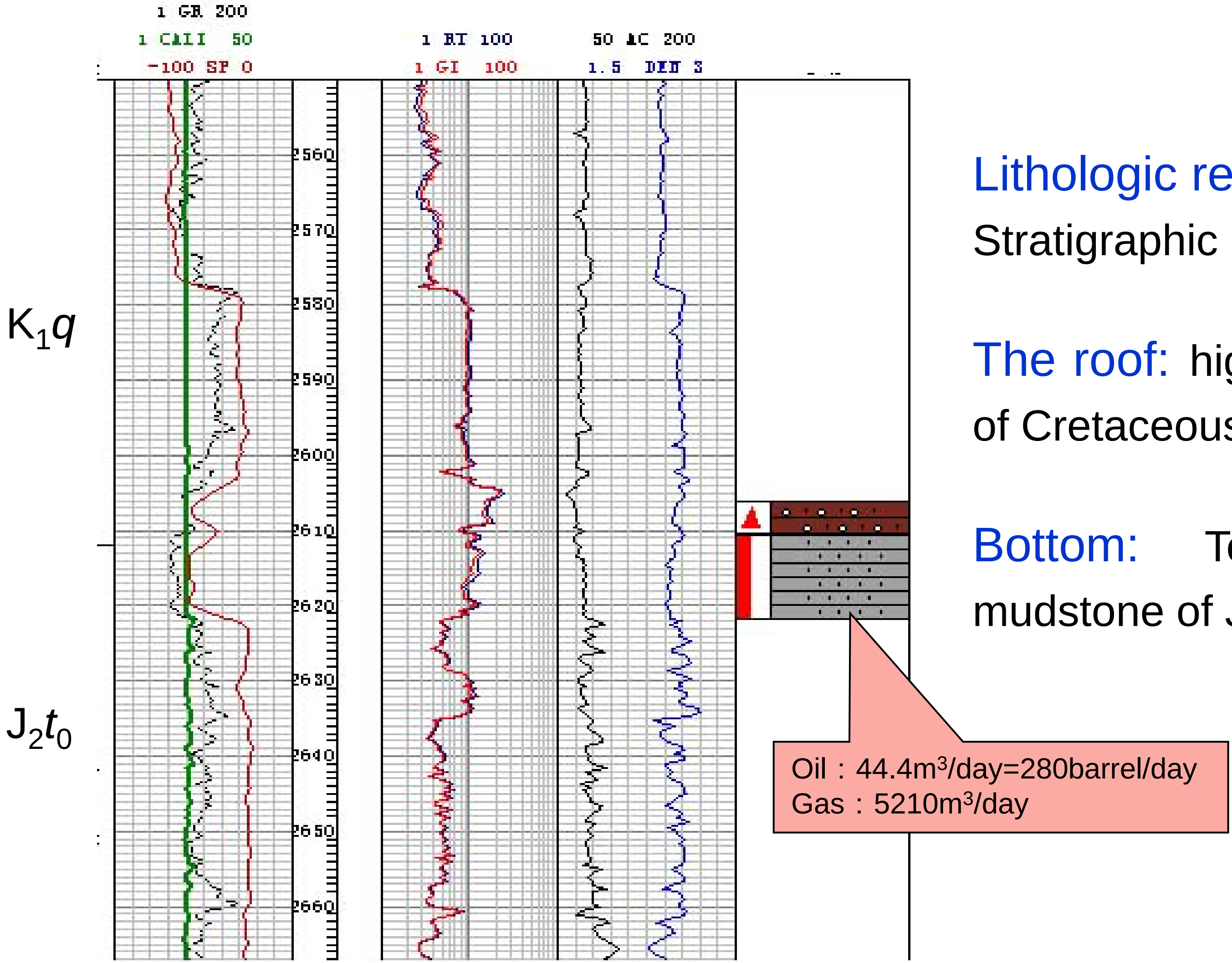
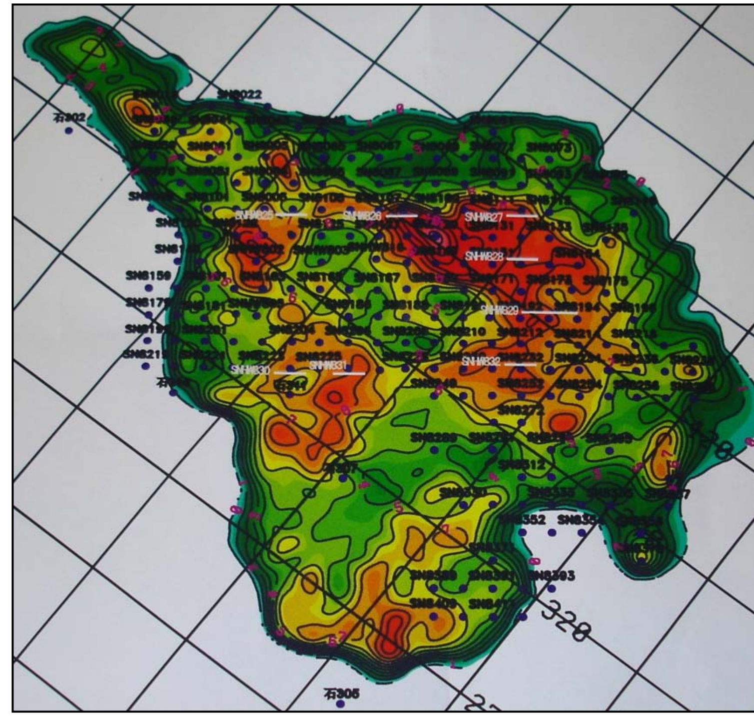



Synthesis Column Map

**Lithologic reservoir type:** Stratigraphic Lithologic reservoir

**The roof:** high gamma mudstone of Cretaceous

**Bottom:** Toutunhe Formation mudstone of Jurassic



**Well SN31 obtaining high-yield industrial oil/gas flow**

**SN31 Oilfield Development Situation ( sandstone thickness map )**

| |
|---|
| Annual output ：about 200,000ton=1.5million barrel |

# OUTLINE

- **BASIC PRINCIPLE**
- **APPLICATION EXAMPLES**
  - a、 Identifing Channels
  - b、 Identifing Stratigraphic Trap
  - c、 Identifing Lithologic Trap
- **CONCLUSIONS**


# CONCLUSIONS

- It is effective to use spectral decomposition method in the thin and discontinuous parts of geological imaging. Such as，identifying channel, lithologic boundary, faults and denudation line.

- A large seismic data can be quickly and effectively evaluated by this method. It plays an effective role during the identification of Lithologic and stratigraphic traps.

- Each prediction method has its own multiplicity and limitation. So it is better to master the geological information and integrated application of various techniques in our study.

# Thanks !

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