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

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

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AAPG 2011 Annual Convention and Exhibition
Houston, Texas 10-13 April 2011
OUTLINE

➢ BASIC PRINCIPLE

➢ APPLICATION EXAMPLES

a、 Identifing Channels
b、 Identifing Stratigraphic Trap
c、 Identifing Lithologic Trap

➢ CONCLUSIONS
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.
The Tuning Cube

Discrete Frequency Energy Cubes

3-D Seismic Volume

Interpret

Interpreted 3-D Seismic Volume

Subset

Zone-of-Interest Subvolume

Compute

Zone-of-Interest Tuning Cube (cross-section view)

Animate

Frequency Slices through Tuning Cube (plan view)

Time-Frequency 4-D Cube

Discrete Frequency Energy Cubes

3-D Seismic Volume

Compute

Frequency 1

Frequency 2

Frequency 3

Frequency 4

Frequency m

Subset

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OUTLINE

➢ BASIC PRINCIPLE

➢ APPLICATION EXAMPLES

a、Identifying Channels
   E.g. C43 Well 3-D Work Area

b、Identifying Stratigraphic Trap

c、Identifying Lithologic Trap

➢ CONCLUSIONS
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.
Combination of more information to improve the reliability of fault interpretation
Strong amplitude Corresponding relations between the plan and section

RMS amplitude Plan (between horizon 1 and 3)
APPLICATION EXAMPLES

- Identifying Channels

Corresponding relation of the Channel on the plan and section

![Diagram showing RMS amplitude Plan (along 1 horizon 40ms) and Frequency Spectrum Amplitude Plan.]

C43 Integrated interpretation chart

Channel identification and analysis methods based on seismic data.
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.
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.

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: 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.
J₁s₂ is delta front deposits, sourced from the north and mainly composed of underwater distributary channel sediments, primarily fine to medium sandstones in the thickness range of 8~25m.

The amplitude plan of spectrum decomposition in J₁s₂

Sedimentary Facies Plan in the J₂x

a. Identifying Channels
OUTLINE

➢ BASIC PRINCIPLE

➢ APPLICATION EXAMPLES

  a、 Identifying Channels
  b、 Identifying Stratigraphic Trap
      E.g. South of XY 2 Well 3-D Work Area
  c、 Identifying Lithologic Trap

➢ CONCLUSIONS
APPLICATION EXAMPLES

b、Identifying Stratigraphic Trap

Trace300 Seismic Section

Trace300 Spectral decomposition phase spectrum section
APPLICATION EXAMPLES

Identifying Stratigraphic Trap

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

![Spectral decomposition phase spectrum section](image-url)
After analysing of the phase plan of the bottom of the Cretaceous (Tk₁), choosing a higher frequency of phase plan to determine the erosion line.
APPLICATION EXAMPLES

Faults-Stratigraphic Trap of Toutonghe Formation (J₂t)

- Structural map of Tj4
- Structural map of Tj₂
OUTLINE

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  a、 Identifing Channels
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  E.g. SN 31 Well 3-D Work Area

➢ CONCLUSIONS
APPLICATION EXAMPLES

Identifying Lithologic Trap

- Logging environmental correction
- Standardized processing

Before: hard to compare
After: good to compare
APPLICATION EXAMPLES

Identifying Lithologic Trap

unconformity between $K_1q$ and $J_2t$

SN3 well horizon calibration

Joint wells section
APPLICATION EXAMPLES

Identifying Lithologic Trap

- **Lithologic trap identification**

![Diagram showing identification of lithologic traps](image-url)
APPLICATION EXAMPLES

Identifying Lithologic Trap

Left: Line103 seismic section (Phase shift 90°)  Right: Full 3-D visualization plan
Top right: Along Tk₁ after flattening down 0-38ms perspective results
Bottom right: Along Tk₁ after flattening down 0-16ms perspective results
APPLICATION EXAMPLES

Identifying Lithologic Trap

Coherence time slices
(along Tk1 after flattening down 14ms)

Time slices
(along Tk1 after flattening down 14ms)

RMS amplitude Plan
( along Tk1 down 0-30ms)

RMS amplitude Plan
( along J2f01 both up and down 15ms)
c. Identifying Lithologic Trap

- Spectral decomposition Phase slice (40Hz, along $T_k_1$ after flattening down 16ms)

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

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APPLICATION EXAMPLES

- Spectral decomposition amplitude spectrum Slice (along $T_{k_1}$ after flattening down 0-50ms, 30Hz)

![Spectral decomposition amplitude spectrum Slice](image)
APPLICATION EXAMPLES

- Spectral decomposition amplitude plan (along $T_{k_1}$)

30Hz

40Hz
c. Identifying Lithologic Trap

- Spectral decomposition amplitude plan (along $J_2t_0^1$)

![Diagram showing spectral decomposition amplitude plans for 30Hz and 50Hz.](image)
APPLICATION EXAMPLES

- **Identifying Lithologic Trap**

  Spectral decomposition amplitude plan (between $T_{k_1}$ and $J_{2t_0}$)

![30Hz](image1.png)

![50Hz](image2.png)

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APPLICATION EXAMPLES

Seismic Facies Analysis and 3-D Visualization

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

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

Average energy plan (along $J_2t_0^1$)
APPLICATION EXAMPLES

Identifying Lithologic Trap

Line103 Gamma inversion Section

Line103 Seismic Section (Phase shift 90°)
c. Identifying Lithologic Trap

Trace468  Gamma inversion Section
Trace468 Seismic Section
(Phase shift 90°)

sandstone pinch-out point
APPLICATION EXAMPLES

Identifying Lithologic Trap

Line 100 Absorption Coefficient Section

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APPLICATION EXAMPLES

About Lithologic Traps

- Trap 1 is an effective trap
- Trap 1 Area: 35km²
- Closed range: 230m

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

- Fault-Stratigraphic trap 2 is mudstone.

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APPLICATION EXAMPLES

3-D visualization of Impedance inversion data volume (between $T_{k_1}$ and $J_{2t_0}$)

Identifying Lithologic Trap
c. Identifying 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.
c. Identifying Lithologic Trap

SN 31 well logging interpretation

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APPLICATION EXAMPLES

Identifying Lithologic Trap

Lithologic reservoir type:
Stratigraphic Lithologic reservoir

The roof: high gamma mudstone of Cretaceous

Bottom: Toutunhe Formation mudstone of Jurassic

Synthesis Column Map

Oil: 44.4 m³/day = 280 barrel/day
Gas: 5210 m³/day
APPLICATION EXAMPLES

Well SN31 obtaining high-yield industrial oil/gas flow

SN31 Oilfield Development Situation

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

SN31 Oilfield Development Situation (sandstone thickness map)
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➢ 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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