A New Method for Determining Paleocurrent Direction Using Imaging Log*

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Abstract

The analysis of paleocurrent direction is one of the important methods for analyzing the sedimentary environment and sedimentary system in the study area. This article presents an attempt to determine the paleocurrent direction by using microresistivity imaging logging data and rose diagrams. The change of paleocurrent leads to the planar anisotropy and the directionality of permeability. Therefore, the flow direction can be determined by analyzing the direction of permeability, which can be determined by means of utilization of electrical imaging logging data. In general, the permeability direction of fluvial sand bodies and channel sand bodies is consistent with paleocurrent direction, which is the application scope of this proposed method.

After pre-processing, such as azimuth correction, acceleration correction, and data equalization, the original data is generated into image data. Then a rose diagram is drawn by using the results of stratified statistics on imaging data after deducting mudstone layers. The direction of the maximum conductivity is the direction of the sector with the largest radius in the rose graph. In water-based mud electrical image logging, the greater the conductivity, the better the permeability of the formation. And the direction of permeability is consistent with the paleocurrent. So the direction of the maximum conductivity can be considered as the flow direction. Finally, one cake-like sample and several standard plugs are used to measure conductivity in different directions and permeability respectively. The experimental results are plotted in polar coordinates and the direction of maximum conductivity and the main direction of permeability can be determined. The proposed method can be verified by comparing the statistical results with petrophysical experiments.

The results of the new method are consistent with the petrophysical experiments. It improves the efficiency and accuracy of paleocurrent analysis and is free from many limitations of conventional approaches such as outcrop observation and manual identification. Provides an effective solution and credible results for paleocurrent analysis using logging data.

A New Method for Determining Paleocurrent Direction Using Imaging Log

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Outline

- Introduction

  Limitations of traditional methods and advantages of new methods

- Methods and Steps

  Preprocessing of imaging data, layered and fan-shaped statistics, determination of paleocurrent direction, comparison with rock physics experiments

- Example and Discussion

  An example of Well X, located in the middle and northern part of the Yishan slope in the Ordos Basin

- Conclusions

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Introduction

- The analysis of paleocurrent direction is one of the important methods for analyzing the sedimentary environment and sedimentary system.
- Traditional palaeocurrent analysis relied on the observation and determination of outcrops in the field. The application is limited by practical conditions. If there is no outcrop or no corresponding signs, the paleocurrent cannot be determined by field observations.
- Microresistivity image logging has been widely used due to its ability to provide high-resolution borehole images. The paleocurrent can be obtained by identifying the sedimentary structure from images. The disadvantage is that the interpreter needs to have certain experience and know the response patterns of various paleocurrent signs.
- The new method can determine the paleocurrent direction by using microresistivity image logging data, simple statistical method and rose diagram. It is free from many limitations of conventional approaches such as outcrop observation and manual identification.

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Methods and Steps

Determining the type of reservoir sand body

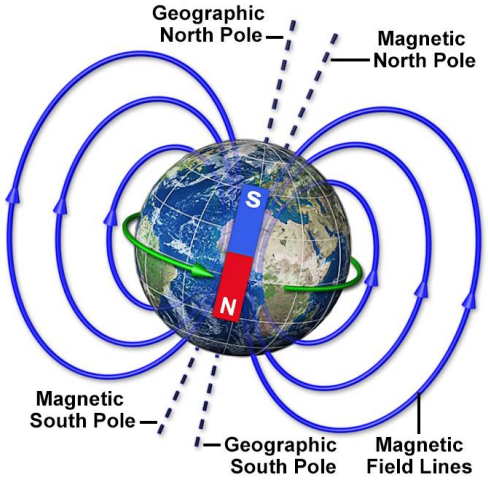
- The change of paleocurrent direction leads to the planar anisotropy and the directionality of permeability.
- The paleocurrent direction can be determined by analyzing the direction of permeability.
- The permeability direction can be determined by using imaging logging data.
- Permeability direction of **fluvial sand bodies and channel sand bodies** is consistent with paleocurrent direction.
- The sedimentary environment and the type of sand bodies can be determined by regional geological data.

Methods and Steps

Preprocessing of imaging data

a. Azimuth correction

The geographic (true) north pole and the magnetic north pole do not coincide, the measured azimuth data needs to be corrected.



$$\phi' = \phi + \delta - \gamma$$

$$\gamma = \Delta\lambda \cdot \sin\psi$$

ϕ' : corrected azimuth

ϕ : measured azimuth

δ :magnetic declination

γ : meridian convergence of the Gauss Plane

$\Delta\lambda$: longitude difference between calculation point and central meridian

ψ : latitude of the calculation point

b. Acceleration correction

Eliminate the phenomenon of stretching and compression in the image caused by borehole inclination, irregularities, and mud cakes, and restore the true depth of the logging data.

Common method : Kalman filter

c. Data equalization

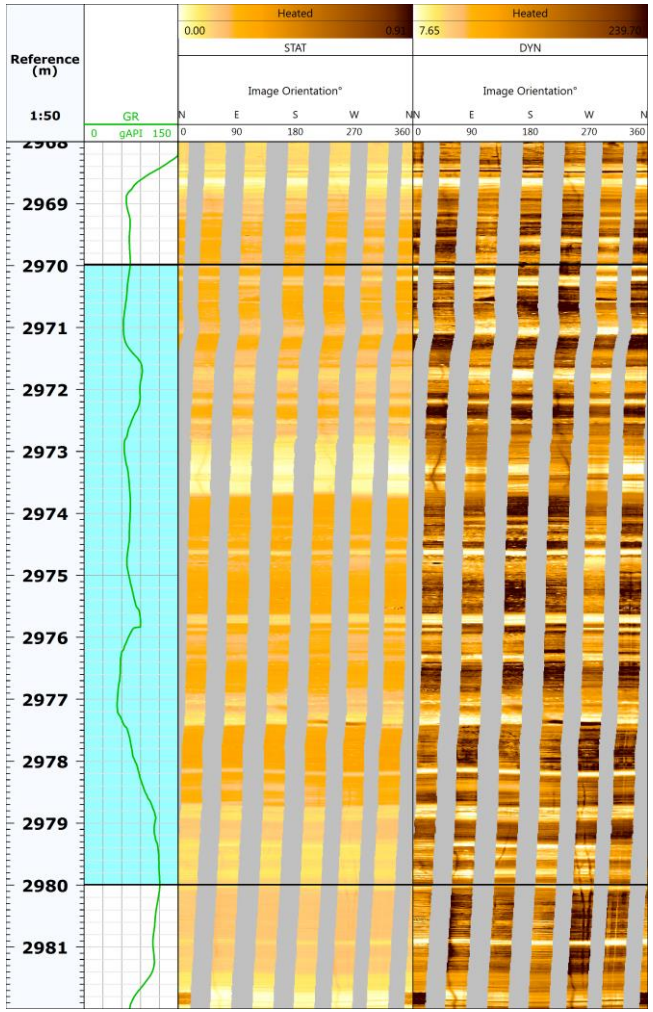
Corrects the effects of different responses between buttons and pads caused by tool.
Eliminate obvious bright or dark areas, black bands or vertical stripes.
Make the response of each button match the global response.

1 2 3 4 5 6 7 8

Methods and Steps

Image creation

- Arrange 2D data according to the orientation of the pad A.
- Create images using static and dynamic calibration methods.
- Static image reflects the overall change of the formation; Dynamic image makes the description of the local features more clear.
- Static image consistent with the instrument response, it is used for subsequent statistical analysis and the dynamic image is used for assisted interpretation.



1 2 3 4 5 6 7 8

Methods and Steps

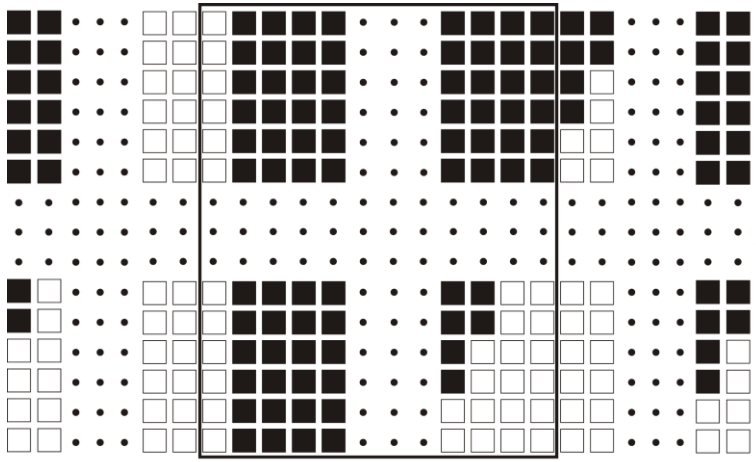
Deducting mudstone layers

Mudstones are generated in a hydrostatic environment and cannot reflect the paleocurrent, this type of layers should be deducted from processed data.

Methods and Steps

Layered and fan-shaped statistics

a. Calculate the average value



Horizontal

- Number of sectors: 24
- Angle of each sector: 15°

Vertical

- Sampling interval: 0.1in (0.00254m)
- Window length: 0.1m
- Sliding step length: 0.05m
- Processing length: 10m

Two problems:

Blank zone & Tool rotation

Result in:

Different number of data within same window length

Solution:

Set threshold to 100

>100, process

<100, discard

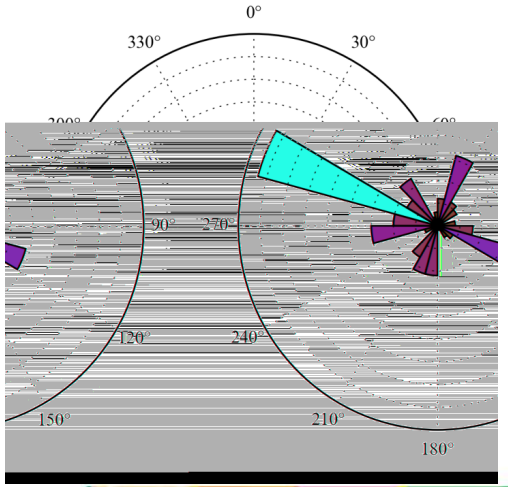
b. Select and output

Select the maximum value, and use the **serial number** of the sector where the maximum value is located as the output of the current window. Move window until the end of the interval.

Methods and Steps

Drawing a rose diagram

- Accumulate the number of occurrences of each sector number.
- Plot the accumulated results in a polar plot.
- Generate a rose diagram that is used to determine the direction in which the maximum value of conductivity appears.
- Radius is proportional to the statistical results.
- Fill color (or grayscale) is related to value



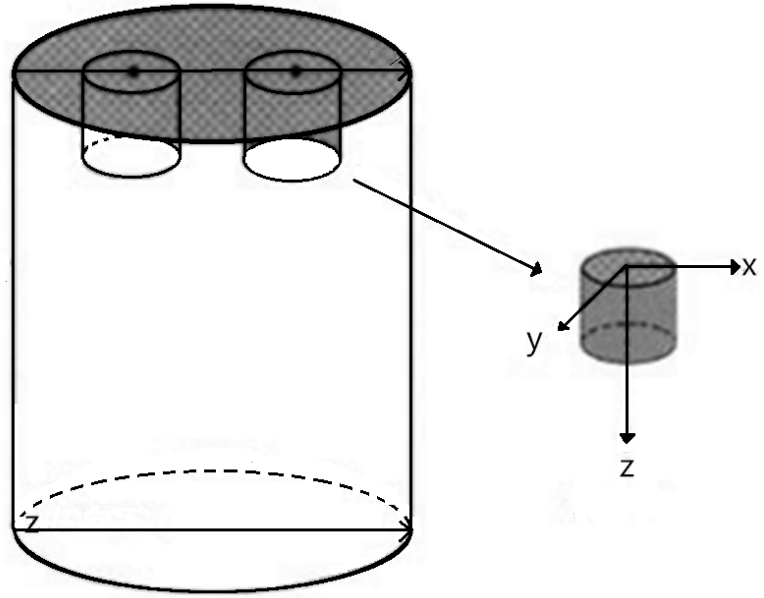
Methods and Steps

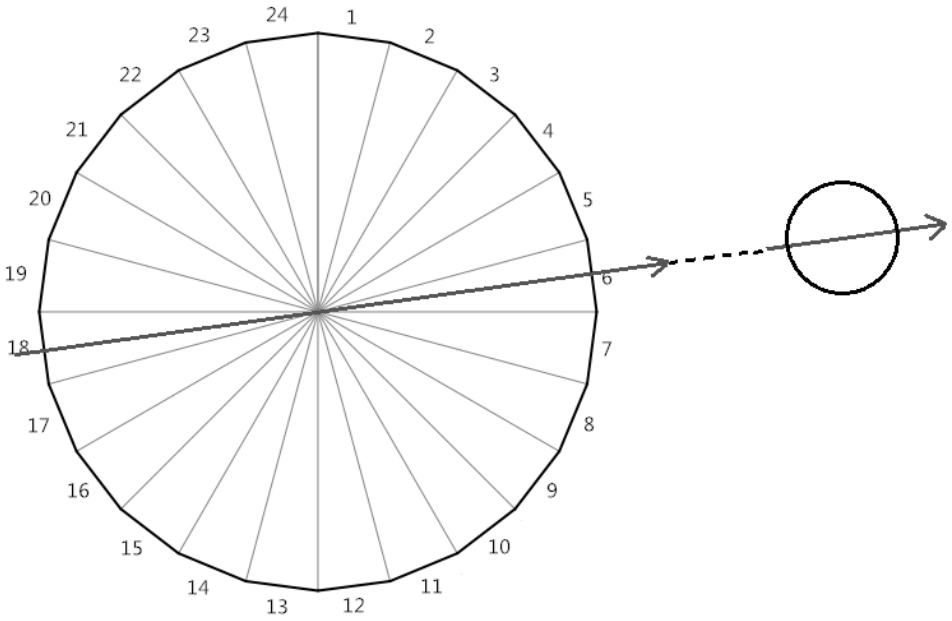
Determination of paleocurrent direction

- The direction of the maximum conductivity is the direction of the sector with the largest radius in the rose graph.
- In water-based mud, the greater the conductivity, the better the permeability of the formation. The direction of permeability is consistent with the paleocurrent.
- The direction of the maximum conductivity can be considered as the direction of paleocurrent.

Methods and Steps

Comparison with rock physics experiments





- Remanence reorientation method
- Cake-like sample: Conductivity measurement
- Standard plugs: permeability measurement
- Draw a polar diagram
- Comparison

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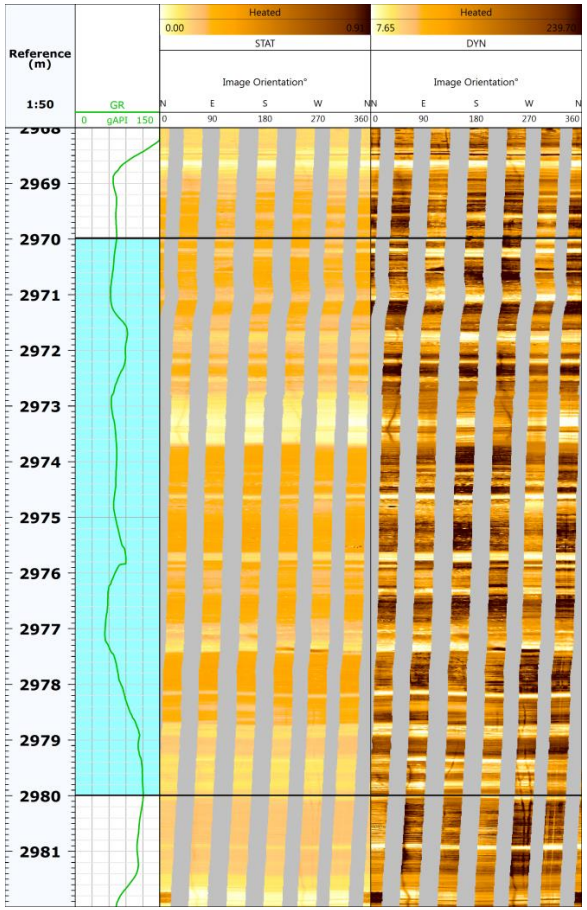
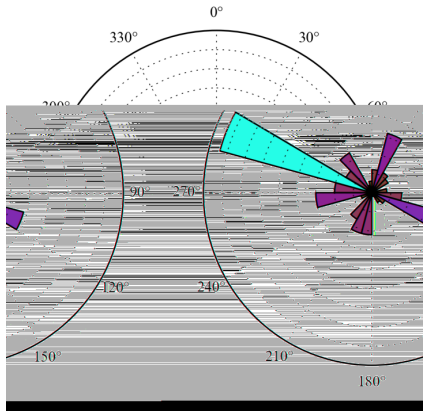
Example and Discussion

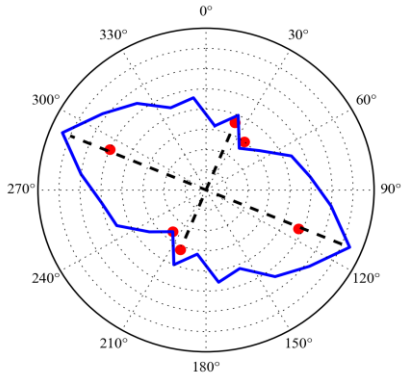
Well X is located in the middle and northern part of the Yishan slope in the Ordos Basin, and the processing interval is the Shan 1 section.



No.	Maximum number	No.	Maximum number
0	6	12	11
1	16	13	11
2	6	14	8
3	5	15	0
4	0	16	3
5	4	17	15
6	8	18	10
7	19	19	42
8	4	20	8
9	3	21	12
10	0	22	2
11	1	23	3

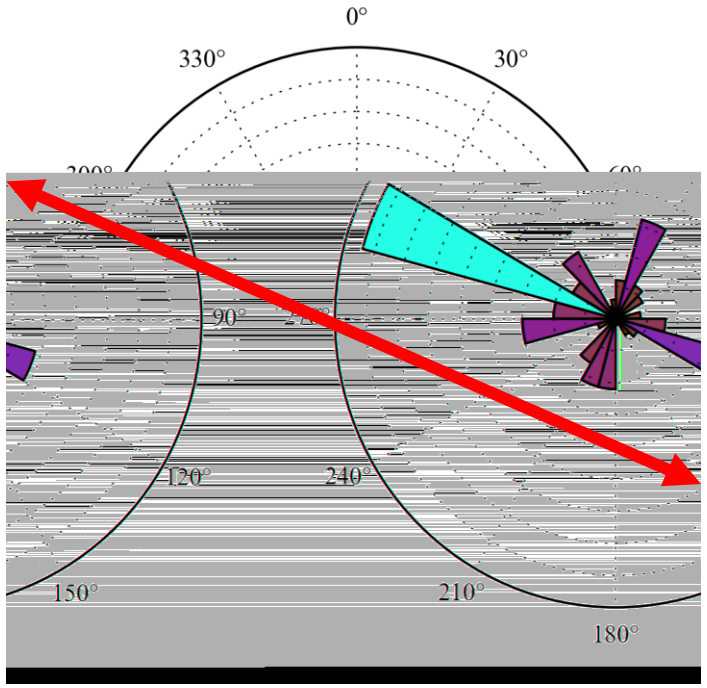


292° (112°)



292.5°(or 112.5°)

Example and Discussion



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Conclusions

Image logging data can be used to determine paleocurrent direction by using data statistics and rose diagram, which overcomes the limitation of field outcrop observations and improve the efficiency and accuracy of paleocurrent analysis. The results of the proposed method are consistent with the petrophysical experiments.

The method can be applied in fluvial sand bodies and channel sand bodies since the permeability direction of these reservoirs is consistent with the paleocurrent direction.

Image logging data must be pre-processed before statistics, including azimuth correction, acceleration correction, data equalization, etc., otherwise the positioning of image data will be incorrect and the accurate paleocurrent direction cannot be obtained.