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CLUSTER ANALYSIS APPLICATION ON PERMEABILITY'S DIRECTION IN NUMERICAL SIMULATION

[1]YUAN Li, [1]YAO Junbo, [2]TAN Junxiang, [3]MA Yujie, [1]LI Guorong, [1]YI Xiangyi, [1]LU Yuan
1. Chengdu University of Technology "State Key Laboratory of Oil and Gas Reservoir Geology and Exploitation"
2. Chengdu University of Technology, College of Earth Sciences, Chengdu, China
3. PetroChina Changqing Oilfield Company Geological Institute of No.8 Oil Production Plant, Shanxi Xi'an 710065,China
Email: [1]lily25788879@163.com

ABSTRACT:

They are permeability scalar data which doesn't has direction in geologic modeling due to lack of data. However, we can get the value and volume coordinate data from the minimum nine-square cube in the gridding model. As a secure and accurate classification methodology in multivariate statistics analysis, the ward-method cluster analyzing can classify the permeability data by clustering slow-changed data in some directions. Then we decompose the permeability into x, y, z directions by three-dimensional space geometric operation. It has an significant impact on improve the numerical simulation accuracy after the processing transformation of permeability data, which provide the basis for the development of the oil field.

Keywords-*Permeability: Direction, Gridding Model, Cluster Analysis, Direction Decomposition*

1. INTRODUCTION

As an important geologic parameter both in history matching and production forecasting for numerical simulation job. When in history matching, horizontal and vertical permeability's accuracy directly impact single well and whole field's oil producing rate and water production's match extent. Meanwhile, if the forecasting of the distribution of pressure, water breakthrough time and remaining oil distribution has an error by using an inaccuracy permeability value, it will has an bad influence on oil field production development plan's early period arrangement and middle-late periods adjustment, which leads to significant failures and major economic damage.

Vertical permeability value always has a sharper fall than horizontal permeability with the increase of the buried depth and formation pressure, and the rock permeability aeolotropy in the formation could be obviously displayed [1-3]. In the oil field development research, we are difficult to obtain the permeability value in all directions. The assessment of the permeability value in anisotropic medium is a very difficult but important job. So many geologic modeling products a permeability gridding model which permeability is scalar and has no direction, but numerical simulation processing do requires three-direction permeability value models.

Universal settlement is assigning three-direction permeability value by using empirical formula, bring in some artificial hypothesis that reservoir's horizontal fracture orientation is accordant, and horizontal permeability value equal to the gridding model values. And we can get the vertical permeability value by multiply the gridding model value by 0.1. However, the method is only a cursory estimate on three-direction permeability value and lack of science and accuracy. To establish the relatively correct water/oil/gas filtering flow mathematical model, we process the data volume which derived from Petrel software by using cluster analysis method of ward. Then we decompose the permeability value into three directions by fetching the angular transformation formula in three-dimensional space geometric operation, It greatly improve the accuracy of the numerical simulation after the process, and provide the basis for the development of the oil field.

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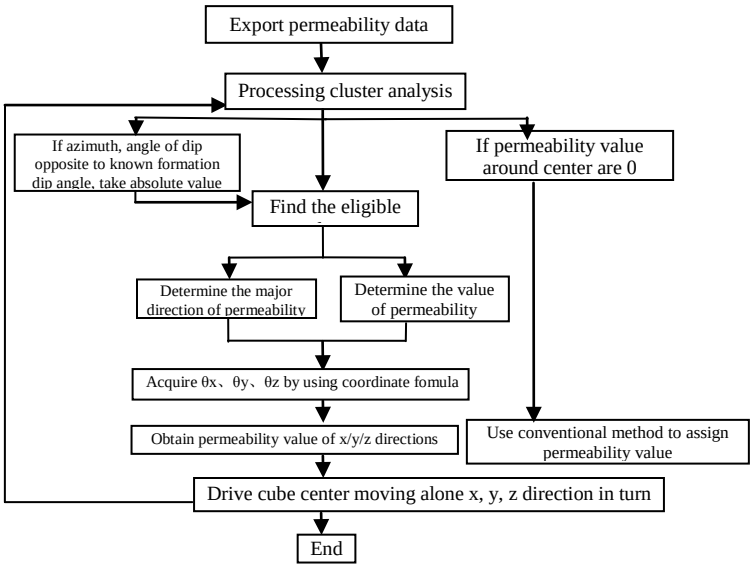

Figure1: Cluster Method And Flow-Process

2. CLUSTER ANALYSIS THEORY AND METHOD SELECTION

2.1 Obtain the distance of data

When the permeability model value data's variation is not so severe, we can analyze the closeness between data by using Euclidean distance calculation formula, and process with Hierachical cluster analysis, we choose ward method for clustering.

Applying Q cluster analysis, primary samples can be clustered by using distant factor as class statistic amount. The smaller the samples distance, the smaller the samples diversity. If the samples distance is big, they are supposed to belong to different classes. Because the ward cluster method based on the analysis of variance require the distance is Euclidean distance, so we use Euclidean distance for distance calculation in this research, and the formula as follows:

$$d(x,y)=\sqrt{\sum_i (x_i-y_i)^2} \qquad (1)$$

2.2 Choosing cluster analysis method

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$$D_{ij}=\|X_i-X_j\|^2 / \left(\frac{1}{n_i}+\frac{1}{n_j}\right) \qquad (2)$$

Dij is distance between sample of I and j, and the distance between sample of l and class composed by I and j is :

$$D^2_{l,ij}=\frac{nl+ni}{nl+ni+nj}D^2_{l,ij}+\frac{nl+ni}{nl+ni+nj}D^2_{L,J}-\frac{nl}{nl+ni+nj}D^2_{i,j}$$

3. PROCESSING THE DESIGN OF EXPERIMENT BY USING CLUSTER ANALYSIS

3.1 The modeling of the experiment and flow-process

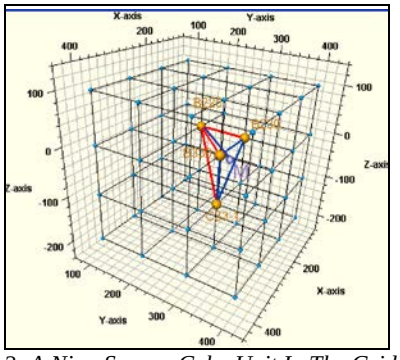

Figure2: A Nine-Square Cube Unit In The Gridding Model

Exported data from petrel modeling software include keyword of "PERMEABILITY" whose short form is perm, where below contains the data volume derived from the model, each value represents the permeability value of each grid, but it has no directions. However, actually in geology

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subsurface situation, it should have directions (permx, permy, permz), Tradition is artificially assignment operation permx = perm ; permy = perm; permz = 1/10perm. Although this approach used empirical formula is of significance to some extent, it is still unscientific.

Permeability value in every grid has a three dimensional coordinate, according to cluster analysis, we search the 27 values in the nine-square cube, and cluster into two classes. Permeability values closed to the value in the center of the cube are class A, the others are class B. We can determine the major direction by pointing to the gravity centre of the permeability values points in class A except for cube center from cube center. And the value of the direction can be acquired by using method of weighted mean. We can decompose this permeability value into the x/y/z directions by using sine and cosine formula. The minimum nine-square cube in the gridding model is show as follow:

Drive the nine-square cube center move alone x, y, z direction in turn, and repeat the steps above, then we can obtain three directions permeability values of values in all the grids. Comparing with conventional method of matrix assignment operation, this method embraces the idea of mathematical geology, and can process matrix assignment operation approximating to actual geology situation when data's variance is small.

3.2 Preparing the testing data

There are permeability values in the modeling grid, the data types of each column must be the same, point of permeability value lies in every grid's upper left corner, process the cluster analysis using nine-square cube as a unit, when run over, the center will move to the next cube center alone x, y, z directions in turn automatically. Considering samples generally have different dimensions, we have to process value data's standardization to put data of different dimensions and different ranges together to compare, and make sure the mean value of each column data is 0 and variance is 1. The testing data are shown as follows:

Table 1: Experiment data

Grid	Perm	DZIM (°)	DEP (°)	X	Y	Z	Standardized PERM	Standardized DZIM(°)	Standardized DEP(°)
A111				10	10				
	0.1	315	45	0	0	100	-0.51217	1.57423	1.04083
A211				20	10				
	0.2	270	45	0	0	100	-0.16903	1.16943	1.04083
A311				30	10				
	0.1	225	45	0	0	100	-0.51217	0.76463	1.04083
A121				10	20				
	0.2	0	45	0	0	100	-0.16903	-1.25939	1.04083
A221				20	20				
	0.3	0	90	0	0	100	-0.44354	-1.25939	2.08167
A321				30	20				
	0.1	180	45	0	0	100	-0.51217	0.35982	1.04083
A131				10	30				
	0.2	45	45	0	0	100	-0.16903	-0.85458	1.04083
A231				20	30				
	0.1	90	45	0	0	100	-0.51217	-0.44978	1.04083
A331				30	30				
	0.2	135	45	0	0	100	-0.16903	-0.04498	1.04083
B110				10	10				
	0.2	315	0	0	0	0	-0.16903	1.57423	0
B210				20	10				
	0.3	270	0	0	0	0	-0.44354	1.16943	0
B310				30	10				
	0.3	225	0	0	0	0	-0.78668	0.76463	0
B120				10	20				
	0.2	0	0	0	0	0	-0.82099	-1.25939	0
B220				20	20				
	0.9	0	0	0	0	0	2.19863	-1.25939	0
B320				30	20				
	0.3	180	0	0	0	0	-0.82099	0.35982	0
B130				10	30				
	0.2	45	0	0	0	0	-0.16903	-0.85458	0
B230				20	30				
	0.9	90	0	0	0	0	2.26725	-0.44978	0
B330				30	30				
	0.8	135	0	0	0	0	2.23294	-0.04498	0

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C11-11				10	10	-			
	0.2	315	-45	0	0	100	-0.16903	1.57423	-1.04083
C21-11				20	10	-			
	0.2	270	-45	0	0	100	-0.16903	1.16943	-1.04083
C31-11				30	10	-			
	0.1	225	-45	0	0	100	-0.51217	0.76463	-1.04083
C12-11				10	20	-			
	0.4	0	-45	0	0	100	-0.40922	-1.25939	-1.04083
C22-11				20	20	-			
	0.3	0	-90	0	0	100	-0.44354	-1.25939	-2.08167
C32-11				30	20	-			
	0.1	180	-45	0	0	100	-0.51217	0.35982	-1.04083
C13-11				10	30	-			
	0.3	45	-45	0	0	100	-0.44354	-0.85458	-1.04083
C23-11				20	30	-			
	0.2	90	-45	0	0	100	-0.16903	-0.44978	-1.04083
C33-11				30	30	-			
	0.9	135	-45	0	0	100	2.50745	-0.04498	-1.04083

3.3 Clustering analysis algorithm

Calculate the distance between standardized samples by using Euclidean formula, and the process can be implemented by SPSS statistical analysis software, and output a similar coefficient distance matrix. Then run the Hierachical Cluster Analysis, input given number of clusters. When analyzing in method modular, we choose ward clustering analysis algorithm. To reveal a clear relationship between samples directly [5], we always use dendrogram to show the result of cluster analysis. And from the figure below, we can clearly see that B230，B330,B220,C33-1 belong to one cluster, and the others belong to another cluster, which exactly match the initial data classification. Therefore we can safely draw the conclusion that ward method clustering analysis can process clustering the data stably and securely, and don't deviate from original geology law of permeability values distribution.

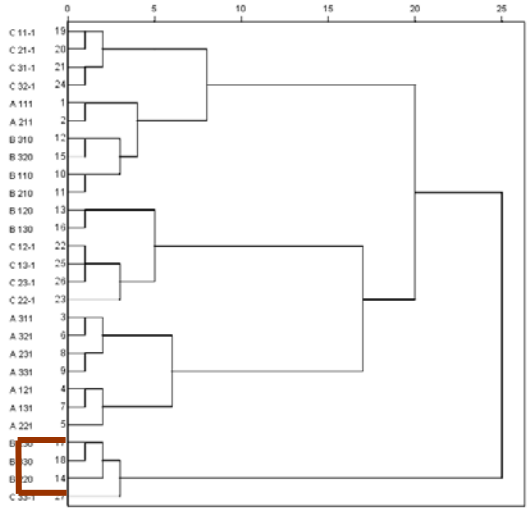

Figure 3: Dendrogram Of Ward Method Cluster Analysis's Result

3. OBTAIN THE PERMEABILITY VALUES OF THE THREE DIRECTIONS BY TRANSFORM THREE-DIMENSIONAL SPACE GEOMETRY ANGLE

4.1 Obtain The Permeability Value Of The Main Direction

Obtain permeability of the main direction and the permeability value of main direction after clustering analysis method finds this kind of category that conform to the conditions. Through the clustering method we can find out n values of the same class which close to the value of centre. Take advantage of Arithmetic average method (such as formula (1)), we obtain the permeability value of the main direction.

$$K = \frac{k_1 + k_2 + ... + k_i + ... + k_n}{n} \quad (4)$$

A. Obtain the main direction of permeability

We have known the three points which belong to the same class form a plane of triangle in space, and also we have known the space coordinates of three points. Firstly, obtain the midpoint coordinates of each side by using the midpoint formula. Secondly obtain Center of gravity M(x0、y0、z0) by using constant ratio formula of internal point of division, and got the formula of center of gravity as following:

$$x_0 = (x_1 + \lambda x_2)/(1+\lambda),\ y_0 = (y_1 + \lambda y_2)/(1+\lambda),$$
$$y_0 = (y_1 + \lambda y_2)/(1+\lambda) \quad (5)$$

Where: λ =1/2

If this number of the kind points is four, we can acquire the direction of permeability by obtain centroid coordinates. If this kind of points' number is more than 4, we can obtain the inclination and the azimuth angle by calculating the weighted average of the tilt angle and azimuth. Thereby we can determine the main direction of permeability.

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4.2 Obtain The Permeability Value Of Three Directions By Transformat Angular In Three-Dimensional

First of all, make projection of the main direction of the permeability to plane xz and yz respectively in the three-dimensional space. According to three-dimensional space coordinates of center M and the point of center of gravity, we obtain θ_{yz}, θ_{xz}. The projection is shown in Figure 5.

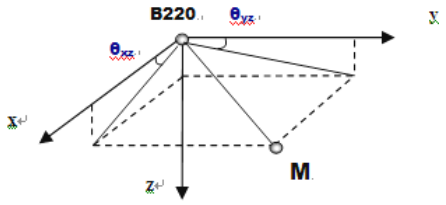

Figure 4: Projection on the three dimensional space

$$\cos\theta_{yz} = (y_0-y_j)/[(y_0-y_j)^2+(z_0-z_k)^2]^{1/2} \quad (6)$$

$$\cos\theta_{xz} = (x_0-x_i)/[(x_0-x_i)^2+(z_0-z_k)^2]^{1/2} \quad (7)$$

$$\theta_{yz} = \arccos(y_0-y_j)/[(y_0-y_j)^2+(z_0-z_k)^2]^{1/2} \quad (8)$$

$$\theta_{xz} = \arccos(y_0-y_j)/[(y_0-y_j)^2+(z_0-z_k)^2]^{1/2} \quad (9)$$

Where: θ_{yz} —the angle between the line of projection to the surface and coordinate axis y

θ_{xz} —the Angle between the line of projection to the surface and coordinate axis x.

The length of the projection to the yz plane L,

$$L=[(y_0-y_j)^2+(z_0-z_k)^2]^{1/2} \quad (10)$$

The length of the main direction line in three-dimensional space:

$$H =[(x_0-x_i)^2 +(y_0-y_j)^2+(z_0-z_k)^2]^{1/2} \quad (11)$$

$$\cos\Phi_{yz} = [(y_0-y_j)^2+(z_0-z_k)^2]^{1/2}/[(x_0-x_i)^2 +(y_0-y_j)^2+(z_0-z_k)^2]^{1/2} \quad (12)$$

where:

Φ_{yz}—the angle between main direction line of permeability and the line of the projection to the yz plane

$$K_{yz} = \cos\Phi_{yz}*K = [(y_0-y_j)^2+(z_0-z_k)^2]^{1/2}/[(x_0-x_i)^2 + (y_0-y_j)^2 + (z_0-z_k)^2]^{1/2}*K \quad (13)$$

$$K_z = \sin\theta_{yz} * K_{yz} = \sin\arccos (y_0-y_j)/[(y_0-y_j)^2+(z_0-z_k)^2]^{1/2}*[(y_0-y_j)^2+(z_0-z_k)^2]^{1/2}/[(x_0-x_i)^2 +(y_0-y_j)^2+(z_0-z_k)^2]^{1/2}*K \quad (14)$$

$$K_y = \cos\theta_{yz}*K_{yz} = (y_0-y_j)/[(y_0-y_j)^2+(z_0-z_k)^2]^{1/2}*[(y_0-y_j)^2+(z_0-z_k)^2]^{1/2}/ [(x_0-x_i)^2+(y_0-y_j)^2+(z_0-z_k)^2]^{1/2}*K \quad (15)$$

Similarly,

$$K_x = (x_0-x_i)/[(x_0-x_i)^2 + (z_0-z_k)^2]^{1/2}*[(x_0-x_i)^2 +(z_0-z_k)^2]^{1/2}/[(x_0-x_i)^2 + (y_0-y_j)^2+(z_0-z_k)^2]^{1/2}*K \quad (16)$$

where:

K_{yz}—the permeability of projection to the yz plane;

Kz—permeability values on the z direction

K_y—permeability values on the y direction; Kx—permeability values on the x direction

Then we can calculate the permeability of the next grid until the calculation of all grids is completed in the work area.

ACKNOWLEDGMENT

In this paper, we process permeability data exported from Petrel modeling software by using clustering analysis method to obtain permeability of the three directions, and process transformation in three dimensional space. This method is scientific and accord with knowledge of geological law o some extent, especially when the single grid unit is small enough. Compared with the experience formula of artificially assign value method, this method has a significant improvement on the grid model permeability value accuracy which could be feasible. This method provides powerful technical support for development plan design of oil fields.

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