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Application of Multivariate Statistical Methods in Provenance Analysis in Mabei Area of Junggar Basin

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Abstract: In the fully consider into the diagenesis,the authors analyzed the provenance of baikouquan formation in Mabei area of Junggar basin by using the methods of heavy minerals. Heavy minerals Q cluster analysis and factor analysis can judge sedimentary period,divide the scope of the different sedimentary system, determine the type of primary and secondary parent rock.ZTR index and contour map can clearly indicate source direction.The results showed that：there are 3 sedimentary systems in the study area, which are the eastern part, the western part and the north central sedimentary area.Eastern sedimentary area is close to the source,and the source is from the north east of the old mountain. The main source rocks are intermediate acid magmatic rocks and volcanic clastic rock, the second is the sedimentary rock;The Western sedimentary area is far away from the source, and the source is from the north west of the old mountain.The main types of the source rocks are acidic magmatic rocks and volcanic clastic rocks,the second is the sedimentary rock;The north central sedimentary area is close to the source, and the source is from the old mountain area in the north.The main source rocks are the neutral magmatic and volcanic clastic rocks, and the second is the sedimentary rock.

Kaywords: *Mabei area; Baikouquan formation; provenance; mineral; multivariate statistics*

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I. INTRODUCE

The Junggar Basin is one of the large oil and gas basins in the northwest of China. The Mahu depression is an important oil and gas producing area of Xinjiang Oilfield Company.The study area is the northwestern margin of the north slope of Mahu depression area, referred to as Mabei area, research horizon for Triassic Baikouquan formation. The lithologic reservoirs are distributed in a group and controlled by facies belts.It is concluded that the Baikouquan Formation belongs to fan delta sedimentary facies, but the study is not deep enough, and the distribution range of sedimentary facies is not clear. The source analysis is the basis for the study of sedimentary facies and sand body distribution. In order to effectively predict the location of lithologic oil and gas reservoirs in this area, provenance analysis has become a top priority.There are many methods for provenance analysis. Because heavy minerals are very sensitive indicators of source change, heavy mineral assemblages can be used to reveal the nature and source of parent rocks[1-3]. Therefore, they are widely used in provenance analysis；the methods of cluster analysis, factor analysis and other statistical methods can reveal the correlation between samples or variables, identify mixed source characteristics, and have been widely used in the analysis of heavy minerals[4-8]. A large number of previous studies have been made on the use of the heavy mineral data in this area.It is mainly used to determine the composition type of heavy mineral components with high content and to divide the sedimentary system, stability coefficient is used to determine the content source direction, the study of sedimentary system in this area has played a certain guiding significance[9-11].But did not take into account the impact of multiple sources of material supply, diagenesis on the distribution of heavy minerals, the deposition system is relatively rough, mixed source characteristics are not identified.Therefore, using the rich heavy mineral data, the author makes a systematic analysis and discussion on the distribution of the source and the distribution system in the area by means of cluster analysis and factor analysis, and taking full account of the influence of diagenesis, so as to provide guidance for oil and gas exploration in the area.

II. REGIONAL GEOLOGICAL BACKGROUND

The northwestern margin of the Junggar Basin is bounded by Zaire and Hala Alat Mountain in the northwest direction of the Junggar Basin, west of Kuitun, east of Xiazijie tectonic belt, including: Hongche fault belt, Kebai fault zone, Wuxia fault belt and Zhongguai uplift and Mahu slope area (east slope area, north slope area, west slope zone and south slope zone)(Fig. 1).Triassic strata in the study area from bottom to top are divided into:Baikouquan formation (T_1b) and Karamay group (T_2k), Baijiantan group (T_3b), the Baikouquan formation purpose layer (T_1b) from the first paragraph can be divided into T_1b_1, T_1b_2 and T_1b_3, T_1b_2 period as the main oil layer.The reservoirs of the Baikouquan Formation are mainly composed of sand and gravel, and the sedimentary background is shallow fan delta deposition in the background of gentle slope. The fan delta plain subfacies and fan delta front subfacies are developed. The front part of each fan is prone to intersecting, Fan range and boundary is not easy to identify.And the north slope of area mainly developed Xiazijie fan delta system, Marcy slope area mainly developed Huangyangquan fan delta system, in order to explore the Xiazijie fan delta distribution and two fan intersection boundary, the study area including Mabei slope area and adjacent parts of Marcy slope.And because the second paragraph is the main oil-bearing section, heavy mineral information is rich, selected as the study horizon.

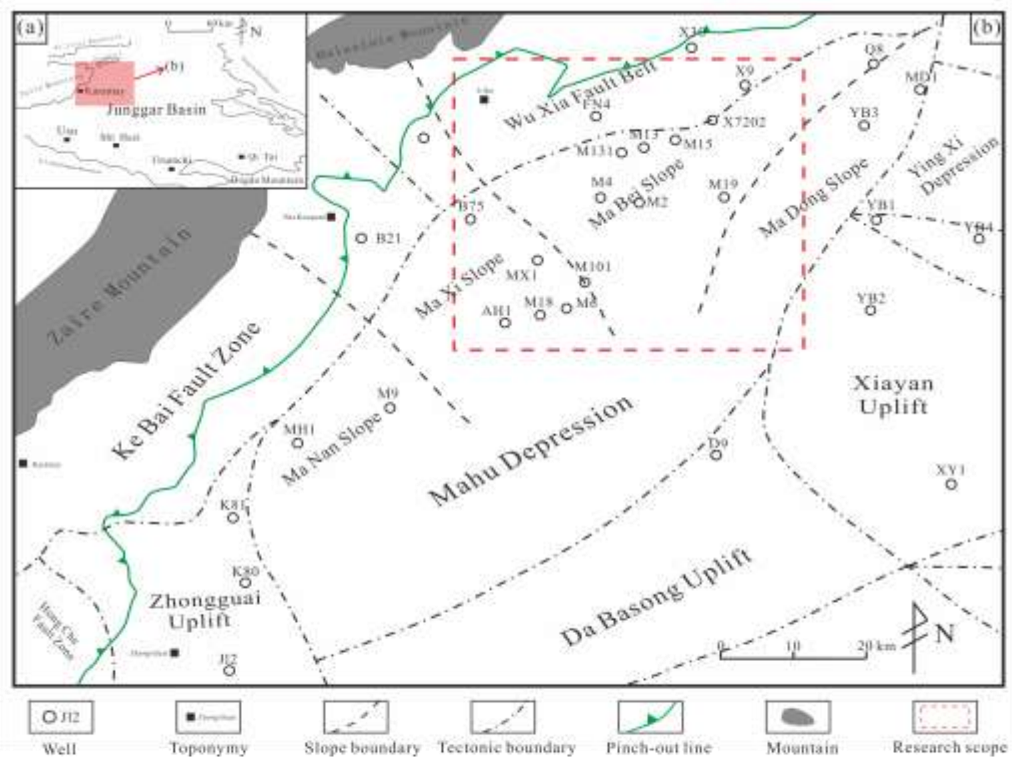

Fig. 1 Tectonic map of the northwest margin of junggar basin (the area of the red dotted line is the research area)

III. PRINCIPLES AND METHODS

Clustering analysis is an effective way to study the problem of "Like attracts like", which can automatically classify samples or variables according to their intimacy in nature without prior knowledge. According to the purpose of the study and the object, the cluster analysis is divided into Q type and R type. Q-type clustering analysis is to study the relationship between the samples, R-type cluster analysis is to study the relationship between variables。Factor analysis can integrate variables with complicated relations into a few independent factors, thus using a few factors instead of the original variables to simplify the analysis[13]。

In the analysis of heavy minerals,the predecessors have done a lot of research on these methods[4-6, 8, 14-18], and the specific ideas are as follows: The sediments formed during geological history are often mixed by multiple stages of sediment supply, and the sediments of the same stage have the same or similar heavy mineral assemblage characteristics;While the sediments of different periods are characterized by different heavy mineral assemblages due to different types of parent rocks.Using Q-type clustering analysis, different groups of samples with different characteristics in the vertical direction can be distinguished as sediments of different periods, each of which represents the supply of sediment for a certain period.On this basis, with the help of R cluster analysis will be processed with heavy mineral data in a period,and the different heavy mineral assemblage types were obtained. The same heavy mineral assemblage type was regarded as the same depositional system, and different deposition zones were divided.Q-type clusters can also be used to analyze the same period of heavy mineral data, each sample group represents a different deposition system, which divided the different deposition area.On the basis of determining the sedimentary system, factor analysis was carried out to identify the characteristics of heavy mineral assemblage and the type of rock in the parent rock area.It should be noted that R-type cluster analysis can also determine the characteristics of heavy mineral assemblage,but could not determine the main and secondary parent rock, and through factor analysis variance of different factors, will be a very good distinction between primary and secondary parent rock.Therefore, cluster analysis and factor analysis have some advantages in studying the sedimentary system with complex parent rocks and mixed source characteristics.

The idea of this study is as follows.Firstly, Q-type cluster analysis of heavy mineral data at different depths of single well was carried out, and the sample groups with the same or similar vertical characteristics were separated as the sediment from the same period. Each sample group represented the same period of sediment supply.Q type clustering analysis takes the square of Euclidean distance, that is, the sum of the squares of the difference of each variable of each sample. The formula is:

$$\text{EUCLID}=\sum_{i=1}^{k}(x_i - y_i)^2 \qquad (1)$$

Of these, K means that there are k variables in each sample; Xi represents the value of the first sample on the i-th variable; Yi represents the value of the second sample on the i-th variable;The clustering method uses an intergroup connection, that is, the distance between two small classes is the average distance between all the samples in two small classes. On this basis, the heavy mineral data of each well in the whole area are analyzed by Q cluster method, and the development range of each sedimentary system is delineated.Generally, the stability factor or ZTR index is used to determine the source direction, but heavy minerals in the study area are greatly affected by diagenesis, zircon, tourmaline and rutile are the most stable in heavy minerals, which are least affected by diagenesis and are almost common in all crystal rocks. Therefore, the ZTR index is used to determine the source direction.Finally, the factor analysis of the heavy mineral data of each depositional system was carried out, and the type of rock was determined by combining the rock type of each source area .In the factor analysis, the principal factor extraction method selects the principal component analysis method and carries out the maximum variance rotation.

IV. HEAVY MINERAL CHARACTERISTICS

The data of 30 Wells and 142 samples were collected in the second section of the study area. The rich data provided the basis for the multivariate statistical analysis. There were 24 kinds of heavy minerals found in the study area, among which the main heavy minerals were epidote (47.13%), titaniumite (11.09%), ilmenite (10.95%) and limonite (10.29%) with an average content of more than 10%. Secondary heavy minerals are magnetite (7.09%), zircon (3.92%), pyrite (3.82%), barite (1.45%), garnet (1.41%), tourmaline (1.04%), with an average content of 1% to 10%. A small amount of heavy mineral is spinel (0.91%), brookite (0.30%), anhydrite (0.21%), augite (0.19%), zoisite (0.17%). Its average content is less than 1%.

V. SOURCE ANALYSIS

4.1 Cluster analysis

4.1.1 Analysis of multi - period source supply

First, the Q-type cluster analysis method is used to separate the sample groups with different characteristics in the vertical direction from the sediments from different periods. Each sample group represents the supply of sediments in a certain period or a certain parent rock type. This method is used to analyze the data of different depth and heavy minerals in single well, and the M001 well is used as an example. There are 15 heavy mineral analysis samples in the second section of the M001 Wells. The heavy minerals mainly include: vermiculite, Limonite, ilmenite, white titanium, Zircon, garnet, Spinel, Tourmaline, titanium Ore, Magnetite, zoisite (Table 1).

Table 1 M001 well heavy mineral content table(%).

Depth(m)	Epidote	Limonite	Ilmenite	Leucoxene	Zircon	Garnet	Spinel	Tourmalin	Brookit	Magnetite	Zoisite
3449.30	44.60	21.10	18.80	6.60	4.20	0.20	1.70	0.00	0.50	0.50	0.50
3450.25	26.00	8.40	52.00	3.30	3.40	0.30	1.10	0.00	0.50	0.70	0.10
3452.44	3.70	34.40	0.80	4.00	7.00	3.10	0.80	0.20	0.80	0.40	1.00
3453.49	0.80	46.20	0.60	12.00	25.00	4.60	2.10	1.70	2.90	0.60	0.40
3455.24	3.00	21.60	0.60	36.60	0.40	0.40	0.20	2.00	0.00	0.60	0.60
3456.12	61.70	1.50	2.10	26.10	0.20	1.30	0.20	2.50	0.00	0.00	0.00
3469.50	88.70	1.30	1.80	6.90	0.30	0.30	0.30	0.00	0.00	0.00	0.00
3470.43	87.00	1.60	2.00	6.40	2.40	0.00	0.30	0.30	0.00	0.00	0.00
3473.34	47.00	15.00	22.50	12.50	1.00	0.70	0.50	0.10	0.00	0.00	0.10
3475.68	19.60	78.40	1.60	0.00	0.10	0.10	0.00	0.00	0.00	0.00	0.10
3477.05	74.80	23.80	0.30	1.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00
3477.89	42.00	44.50	5.00	0.50	0.00	0.00	0.00	0.20	0.00	0.00	0.00
3486.46	54.00	44.50	0.50	0.00	0.00	0.70	0.00	0.30	0.00	0.00	0.00
3487.87	43.60	35.80	19.30	0.00	0.50	0.50	0.20	0.00	0.20	0.00	0.00

3490.60	26.20	61.60	7.00	1.40	1.10	1.90	0.00	0.10	0.00	0.00	0.00

The Q-cluster analysis of these 15 samples was carried out, and the Q-type cluster analysis spectrum of M001 wells was obtained (Fig. 2). When the class spacing is 11, all the samples are vertically clustered into one category, that is, these samples have the same or similar heavy mineral combination characteristics, indicating that M001 wells have experienced a period of deposition process. The above methods were used to analyze the well bits of M003, M006, M9 and other heavy minerals with more than 10 samples were analyzed. The results showed that the second stage of the study area experienced a sedimentary supply process.

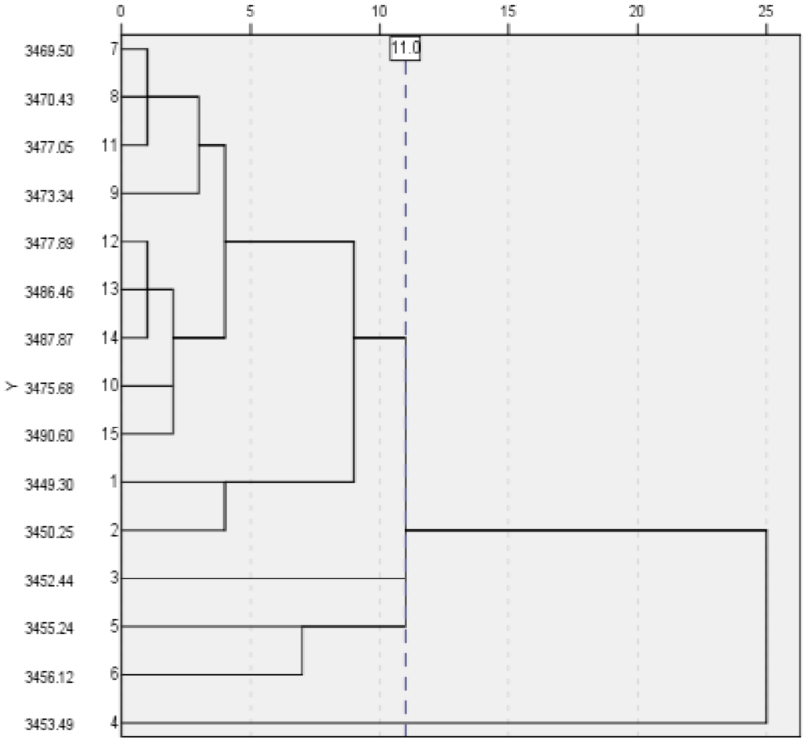

Fig. 2 Q-type clustering spectra of heavy minerals in M001 well.

4.1.2 Depositional system division

Different sedimentary systems show different combinations of heavy minerals because of different parent rock types, so that the development range of each sedimentary system can be delineated according to the results of Q-type cluster analysis. Since the Baihua Quaternary section is mainly subjected to a process of sediment supply, the heavy mineral data for each well is averaged (Table 2), which makes it more accurate to reflect the heavy mineral content of single well. And then Q-type clustering analysis of all well heavy mineral data, Q-type clustering analysis spectrum (Fig. 3).

Table 2 Study area hHeavy mineral content table(%).

Well	Epidote	Limonite	Magnetite	Leucoxene	Ilmenite	Zircon	Tourmaline	Rutile	Pyrite	Spinel
X9	24.88	34.81	3.24	24.76	7.47	0.42	1.32	0.00	0.00	0.04
X723	60.67	3.18	5.00	22.43	3.08	2.45	0.17	0.00	1.1·2	0.15
FN11	42.13	6.30	3.70	30.07	0.00	5.87	0.67	0.00	8.53	0.70
FN15	51.17	7.37	11.43	17.10	4.77	2.47	2.30	0.00	0.97	0.00
M11	50.93	23.53	0.00	8.53	12.67	0.57	0.33	0.00	0.27	0.10
M16	62.10	2.60	4.50	15.20	1.60	3.20	0.60	0.00	7.10	0.00
M002	47.90	24.08	0.00	12.36	9.44	3.50	0.26	0.00	0.14	0.04
M004	57.90	1.20	0.00	35.93	1.23	2.90	0.13	0.00	0.00	0.07
M001	41.51	29.31	0.19	7.82	8.99	3.04	0.49	0.00	0.17	0.49
M101	36.80	27.43	0.00	18.78	6.73	5.13	0.25	0.00	2.08	1.68
AH012	71.70	4.40	2.80	10.60	0.00	0.00	0.00	0.00	2.20	0.00
AH7	31.80	12.80	22.85	16.80	5.15	4.65	1.75	0.00	2.55	1.70
MX1	16.73	16.90	10.63	5.80	11.87	5.17	1.53	0.00	17.37	1.67
AH2	7.95	4.30	19.30	2.15	7.50	14.35	1.55	0.00	23.95	2.60
M18	12.80	8.35	22.20	8.08	12.55	12.90	1.55	0.00	8.40	2.53

M601	15.02	5.91	35.06	19.03	1.06	16.31	0.47	0.00	2.31	3.59
AH011	18.80	8.50	26.80	11.40	4.40	14.00	5.50	0.00	0.00	8.10
X75	3.70	11.00	1.50	0.00	68.40	2.90	0.70	0.00	7.40	0.70
X81	31.05	3.45	0.55	1.05	51.15	3.35	2.05	0.00	0.25	0.80
X55	77.40	0.00	0.00	0.00	20.00	1.40	0.00	0.00	0.00	1.00
X89	82.00	2.70	2.30	3.90	5.10	0.80	0.00	0.00	3.10	0.00
M15	75.85	2.00	4.60	4.85	5.95	1.10	0.70	0.00	2.45	0.00
M7	94.00	0.10	0.00	2.05	0.35	0.65	0.80	0.00	0.05	0.00
M13	56.83	1.70	3.05	1.03	31.30	1.93	0.00	0.00	0.58	0.28
M131	76.03	3.00	1.27	6.37	12.20	0.53	0.10	0.00	0.00	0.20
M132	60.70	6.15	11.45	1.90	11.85	1.40	0.00	0.00	4.20	0.00
M133	60.60	2.00	11.60	1.00	15.70	1.00	1.00	0.00	5.10	0.00
M134	50.60	9.50	6.85	11.83	8.83	3.95	1.58	0.00	3.45	0.18
M136	73.20	6.44	2.94	10.63	1.11	2.33	0.40	0.00	1.00	0.36
M006	81.33	5.83	0.00	4.58	3.40	2.22	0.25	0.00	0.04	0.39
M003	73.56	10.31	0.00	4.58	6.49	1.75	0.42	0.00	0.29	0.38

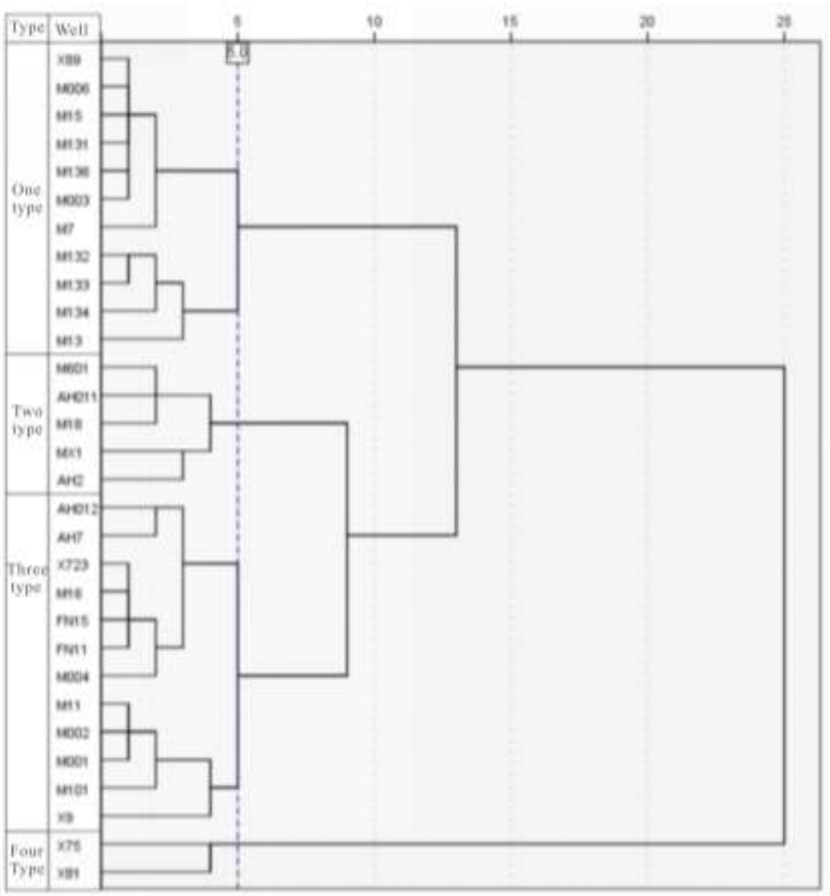

Fig. 3 Q-type clustering spectra of heavy minerals in the study area.

When the class spacing is 13, all the samples are obviously divided into 4 categories, and the contents of various heavy minerals are shown in table 3. The analysis found that the first and third kinds of heavy minerals are epidote, ilmenite, leucoxene - limonite, wells distribution similar to that belong to the same sedimentary system, called the first area. It is important to note that the diagenetic environment in the study area is prone to produce authigenic epidote[19, 20], the first class was clustered alone, because of high content of epidote, widely developed authigenic epidote, showed that the firs class of late diagenesis effect. The second type of heavy mineral assemblage is Magnetite - lacquered stone - zircon - pyrite, called the second zone. The fourth type of heavy mineral assemblage is ilmenite-lacquered stone-Limonite-barite, called the third zone (Fig. 4).

Table 3 Content of heavy minerals in each category(%).

	N=11	ZTR	Epidote	Ilmenite	Leucoxene	Limonite	Magnetite	Pyrite	Zircon	Garnet	Barite	Tourmaline
One type	Average	2.08	71.34	9.30	4.79	4.52	4.01	1.84	1.60	0.70	0.60	0.48
	Minimum	0.63	50.60	0.35	1.00	0.10	0.00	0.00	0.53	0.00	0.00	0.00
	Maximum	5.53	94.00	31.30	11.83	10.31	11.60	5.10	3.95	2.35	1.25	1.58
Two type	N=5	ZTR	Magnetite	Epidote	Zircon	Pyrite	Leucoxene	Limonite	Ilmenite	Garnet	Spinel	Barite
	Average	14.67	22.80	14.26	12.55	10.41	9.29	8.79	7.47	4.26	3.70	3.44
	Minimum	6.70	10.63	7.95	5.17	0.00	2.15	4.30	1.06	0.22	1.67	0.64
	Maximum	19.50	35.06	18.80	16.31	23.95	19.03	16.90	12.55	9.80	8.10	9.35
Three type	N=12	ZTR	Epidote	Leucoxene	Limonite	Ilmenite	Zircon	Magnetite	Pyrite	Barite	Tourmaline	Garnet
	Average	4.14	47.55	19.62	14.07	6.62	3.85	2.78	2.31	0.87	0.59	0.58
	Minimum	0.90	22.85	7.82	1.20	0.00	0.42	0.00	0.00	0.00	0.00	0.00
	Maximum	7.20	71.70	35.93	34.81	16.80	12.80	11.43	8.53	5.35	2.30	1.75
Four type	N=2	ZTR	Ilmenite	Epidote	Limonite	Barite	Pyrite	Garnet	Zircon	Tourmaline	Magnetite	Spinel
	Average	4.50	59.78	17.38	7.23	4.73	3.83	3.80	3.13	1.38	1.03	0.75
	Minimum	3.60	51.15	3.70	3.45	2.05	0.25	3.70	2.90	0.70	0.55	0.70
	Maximum	5.40	68.40	31.05	11.00	7.40	7.40	3.90	3.35	2.05	1.50	0.80

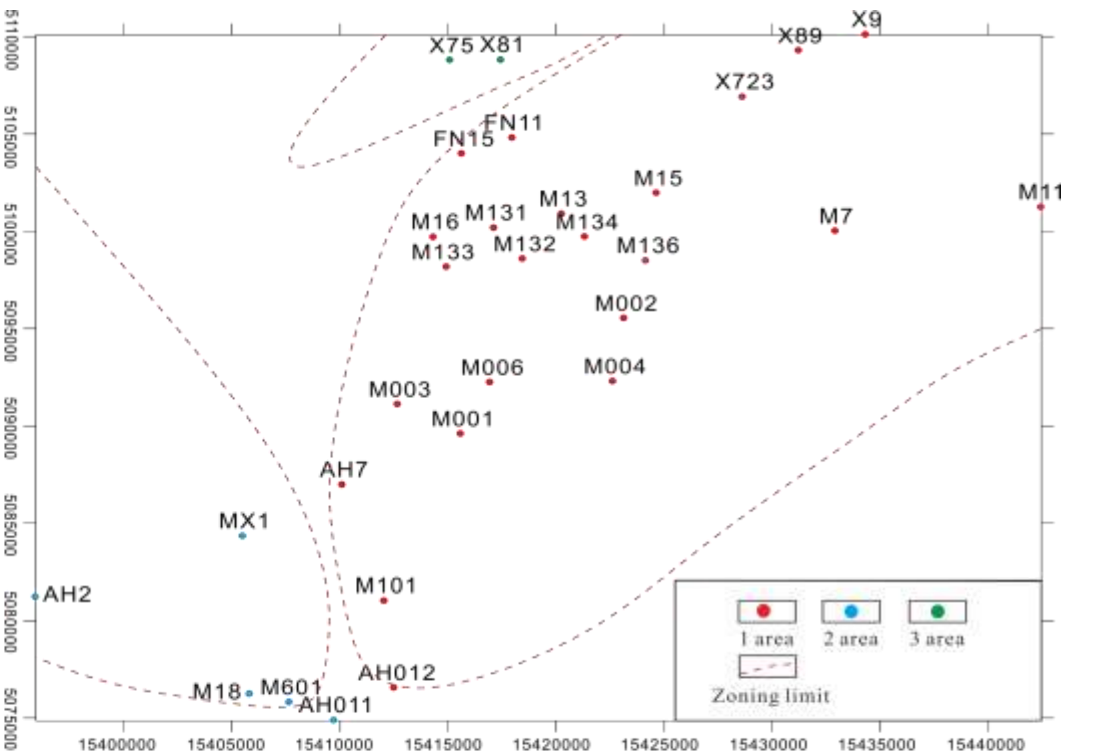

Fig. 4 The study area sedimentary system division diagram.

4.2 The source direction judgment

On the basis of the above Q type cluster analysis and the determination of different sedimentary systems, the contour map of ZTR is traced and the direction of the source is determined. That is, the first and third types belong to the first area, but the heavy minerals in the first category by the serious effect of diagenesis, the source of this information is weakened, the first area mainly selected heavy minerals in third ZTR outline contour map. From the ZTR contour map (Fig. 5), the stability coefficients of the first and third regions are low, usually 1-6, which belongs to the product of near-source deposition, and the stability coefficient of the second zone is higher, usually 6-21 , Is far from the source of the product. The stability coefficients of heavy minerals in the first and three districts increased from north to South and West, indicating that the provenance of the first and three districts came from the North East, the stability coefficient of the second zone is increased from northwest to south east, and the source is from the northwest.

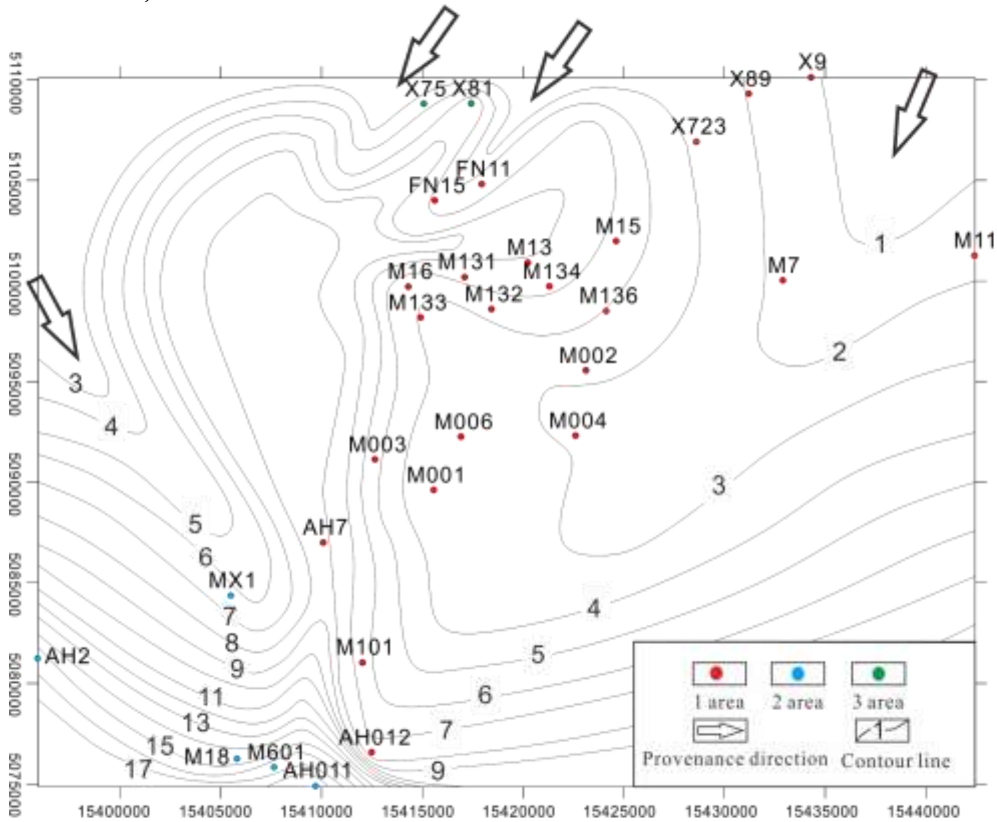

Fig.5 Q-type clustering and ZTR contours of heavy minerals in the study area.

4.3 Factor analysis - defining the parent rock type

The heavy mineral samples in 3 sedimentary areas were analyzed by factor analysis to determine the combined characteristics of heavy minerals, and then to determine the types of parent rocks and their primary and secondary sources. The sample wells in the first district are mainly distributed in the eastern part of the study area. In the factor analysis, three common factors, F1, F2 and F3, are extracted according to the principle of eigenvalue greater than 1, and their cumulative contribution rate is 84.147% (Table 4), which can reflect the basic information of the original data. As can be seen from the table, factor F1 and F3 provide a contribution rate of 60.134% of the total contribution rate, indicating that factor F1 and F3 control are the major sources. The heavy mineral assemblage characteristics of ilmenite + magnetite + pyrite + leucoxene, tourmaline + epidote + limonite, manifested as magmatite rock types,combined with the rock type of the source area, magmatic rocks include mid-acid magmatic rocks and volcanic clastic rocks; The factor F2 provides a smaller contribution rate of 24.013%, indicating that the factor F2 controls the secondary source. From the higher factor load values it can be seen that the heavy mineral assemblage represented by the factor F2 is characterized by limonite + zircon + garnet, expressed as sedimentary rocks of the parent rock type.

Table 4 Total variance and factor loading matrix explained by one area sample.

Total variance explained				Rotational component matrix			
Element	Initial eigenvalue	Variance/%	Accumulate/%	variable	Element		
					1	2	3
1	3.788	37.875	37.875	Ilmenite	-0.98	0.035	0.058
2	2.401	24.013	61.889	Pyrite	0.876	0.164	0.013
3	2.226	22.259	84.147	Leucoxene	0.762	-0.529	0.066
4	0.992	9.92	94.067	Magnetite	0.683	-0.283	0.189
5	0.376	3.758	97.826	Zircon	0.661	0.455	-0.269
6	0.202	2.024	99.85	Garnet	0.094	0.966	0.113
7	0.015	0.15	100	Barite	-0.167	0.887	0.063
8	3.16E-16	3.16E-15	100	Tourmaline	0.152	-0.087	0.958
9	-4.52E-17	-4.52E-16	100	Epidote	-0.028	-0.093	-0.924

10	-4.65E-16	-4.65E-15	100	Limonite	-0.556	0.301	0.713

The sample wells in the second area are mainly distributed in the western part of the study area. According to the above method, four common factors, F1, F2, F3 and F4, are extracted in the spatial factor analysis, and their cumulative contribution rate is 99.1% (Table 5), which represents most of the original data. The contribution rate of factor F2, F3 and F4 accounted for 61.91% of the total contribution rate,indicating that the factors F2, F3 and F4 control the main source. The heavy mineral assemblage is characterized by limonite + borage + magnetite, zircon + garnet, barite + ilmenite, which is characterized by the type of rock of magmatic rocks, combined with the rock type of the source region, it is believed that magmatic rocks include acid magmatic rocks and volcanic clastic rocks. The heavy mineral assemblage characteristic of F1 is characterized by white titanium + pyrite + tourmaline, belonging to the parent rock type of sedimentary rock, the contribution rate is 38.09%, which means that factor F1 controls the secondary source.

Table 5 Total variance and factor loading matrix explained by two area sample.

Total variance explained				Rotational component matrix				
Element	Initial eigenvalue	Variance /%	Accumulate/ %	Variable	Element			
					1	2	3	4
1	3.809	38.09	38.09	Leucoxene	0.969	0.214	0.114	0.045
2	3.5	35.002	73.092	Pyrite	-0.954	0.099	0.278	0.057
3	1.443	14.433	87.525	Tourmaline	0.775	0.227	-0.107	-0.579
4	1.248	12.475	100	Limonite	-0.091	-0.99	0.029	-0.106
5	1.72E-15	1.72E-14	100	Epidote	0.136	-0.881	-0.333	-0.309
6	5.69E-16	5.69E-15	100	Magnetite	0.561	0.821	-0.093	0.045
7	3.73E-16	3.73E-15	100	Zircon	-0.067	0.081	-0.967	-0.232
8	2.50E-16	2.50E-15	100	Garnet	-0.504	0.307	0.805	-0.068
9	1.40E-16	1.40E-15	100	Barite	-0.018	0.453	-0.075	0.888
10	-3.88E-16	-3.88E-15	100	Ilmenite	-0.074	0.087	0.528	0.842

The third sample wells are mainly distributed in the north of the study area. According to the above principle, three common factors, F1, F2 and F3, are extracted in the spatial factor analysis, and their cumulative contribution rate is 100% (Table 6), which can represent all the original information. The contribution rate of factor F1 and F2 accounted for 81.58% of the total contribution rate, indicating that factor F1 and F2 control are the main sources. The heavy mineral assemblage is characterized by garnet + tourmaline + titaniumite + spinel, zircon + ilmenite + boulder + barite, which is represented by the parent rock type of magmatic rock. Combined with the rock type of the source region, the magmatic rocks are considered to include neutral magmatic rocks and volcanic clastic rocks. The factor F3 provides a small contribution rate of 18.42%, indicating that the factor F3 controls the secondary source. From the higher factor load value it can be seen that the heavy mineral assemblage represented by the factor F3 is characterized by limonite + pyrite, belonging to the type of parent rock of sedimentary rocks.

Table 6 Total variance and factor loading matrix explained by three area sample.

Total variance explained				Rotational component matrix			
Element	Initial eigenvalue	Variance /%	Accumulate /%	Variable	Element		
					1	2	3
1	4.618	46.181	46.181	Garnet	0.998	0.062	0.009
2	3.54	35.397	81.578	Tourmaline	0.996	-0.088	0.005
3	1.842	1.84E+01	1.00E+02	Leucoxene	0.995	-0.011	-0.102
4	5.23E-16	5.23E-15	1.00E+02	Spinel	0.931	0.363	-0.043
5	3.50E-16	3.50E-15	1.00E+02	Zircon	-0.044	0.968	-0.248
6	2.83E-16	2.83E-15	1.00E+02	Ilmenite	0.218	0.934	0.281
7	1.43E-16	1.43E-15	1.00E+02	Epidote	-0.559	-0.758	-0.337
8	-5.29E-18	-5.29E-17	1.00E+02	Barite	-0.421	0.713	0.561
9	-1.05E-16	-1.05E-15	1.00E+02	Limonite	0.049	-0.061	0.997
10	-2.25E-16	-2.25E-15	1.00E+02	Pyrite	-0.085	0.239	0.967

VI. CONCLUSION

1) There are 3 major depositional systems in the study area, they are the eastern sedimentary area, the Western sedimentary area and the north central sedimentary area.
2) The eastern sedimentary area is the product of near source deposits, and the provenance comes from the old mountain area in the east of the north. The mother rock types are mainly magmatic rocks, including intermediate acid magmatic rocks and pyroclastic rocks, and then sedimentary rocks; The Western sedimentary area is the product of distant source deposits, and the provenance comes from the old mountain area in the west of the north. The mother rock types are mainly magmatic rocks, including acid magmatic rocks and pyroclastic rocks, and then sedimentary rocks; the northern sedimentary area is the product of near source deposits, and the provenance is from the old mountain areas in the north. The mother rock types are mainly magmatic rocks, including neutral magmatic rocks and pyroclastic rocks, and then sedimentary rocks.
3)The study found that two sedimentary system mainly exists in Mabei area,namely, the first area which the combination of heavy mineral assemblages are the erglass - ilmenite - titanite - limonite and the third area which heavy mineral assemblages are ilmenite - iron ore - barite .The M101 wells in the field are the boundaries of the Xia Zijia fan delta and the Huangyangquan fan delta, and this study found that the Xia Zijia fan delta crossed the M101 well and extended to the AH012 well, possibly extending further and hoping to arouse future attention.

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