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The identification of unconformity and the reconstruction of ancient landform in Hailar Basin

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Abstract: Hailar Basin is a haft-graben fault basin which suffered multi-stage tectonic transform, are formed by multiple mono-basins which superimposed and compound in multi-direction and has complex structures. Stratigraphic unconformity is as the famous hydrocarbon migration pathways system in Hailar Basin.Its identification, restoration and reconstruction of ancient landform have very important significance. By means of composite analysis of the information of seismic, well logging and geology we identified the characteristics of denudation areas of layers in Hailar Basin. On this basis utilizing restoring method of layers restored denudation thickness in plan, using Vue 5 Esprit restored three-dimensional diagramins of the ancient landform of every depression in the basin in each geologic history period and then analyzed the ancient landform and the paleoenvironment.

Keywords: *Hailar Basin, the identification of unconformity, the reconstruction of ancient landform, neural network regression algorithm, restoring method of layers*

I. INTRODUCTION

The Hailar basin suffered multiple tectonic movement periods and its motion property is complex, which makes it hard to restore the strata denudation thickness. In order to solve this problem, many geologists conducted in-depth research from different angles, and has put forward the methods of recovery of strata denudation, which are summed up in the following 4 categories: (1) the Wyllie model method, such as sound wave time difference method, porosity data method (Magara, Henry, 1976; 1996; Liu Jingyan. 2000); (2) stratigraphic contrast method, such as the traditional stratigraphic contrast method, seismic stratigraphic contrast method (Li Wei, 1996; Mou sea, 2002); (3) related to palaeotemperature scale, such as vitrinite reflectance, homogenization temperatures fluid inclusion, apatite fission track dating (He Sheng, 1989; Li Wei, 1996); (4) sedimentary ratio analysis, such as the sedimentary ratio analysis, such as wave analysis of sedimentary basin and so on(Liu Guochen, 1995; Zhang Yiwei, 2000).

The paper is focused on the identification and restoration of the unconformity in the basin. There are a lot of methods to restore the stratum denudation thickness, and each method has its own application condition. The methods related with porosity (including sound wave time difference method) requires that the denudation thickness is greater than the depth of burial, and the effect of diagenesis on porosity also affects the analysis results. The errors caused by velocity logging, such as the presence of microcracks in the vicinity of the active tectonic belts, can lead the measured value of the acoustic travel time to being too large. The paleotemperature scale is vulnerable to the transformation of volcanic eruptions, frictional heating of reversed faults and other tectonic heat events which in the formations the final paleotemperature record and the buried depth is undermining in the positive correlation [1]. Stratigraphic contrast method needs to the no erosion area in the study area to compare and meanwhile also takes into account the differences caused by the thickness of sedimentary depositional environment. The sedimentary ratio analysis and wave analysis also has a series of assumptions which require research the study area conforms to the given conditions, the results of the study have multiple solutions. There has not be a perfect method of study on the denudation thickness, which only according to the geological condition in the actual area and the available data we selected appropriate methods, used a variety of methods to calculate the comprehensively results, and verified each other[2].

II. THE DISTRIBUTION CHARACTERISTICS AND THE PHYSICAL PROPERTIES IN PRESENT FORMATIONS

Wuerxun depression from bottom to top develops Budate group in Triassic, Xinganling group in upper Jurassic, Tongbomiao group in lower Crataceous, Nantun group, Damoguaihe group, Yimin group, Qinggangyuan group in upper Crataceous, Paleogene-Neogene and Quaternary.

According to its characteristics, what mainly are investigated in the aspects of formation physical are characteristics of interval transit time, characteristics of sandstone porosity, vitrinite reflectance, characteristics of seismic reflection and then analyze evidences of denudation in burial history of stratigraphy.

Characteristics of interval transit time

The propagation time of acoustic wave in the vicinity of the ground (equivalent to pure water) is about 591-689 s/m (s /ft 180-210), and the propagation time in the rock matrix is between 128-223 s/m (s /ft 39-68). If the curve extends to the surface, close to the theoretical value, it expresses the normal compaction of the burial process, which there is no deviation of the curve caused by the erosion.

Interval transit time curves which are represented by Wu27 well and Wu17 well are close to straight lines on semilog coordinate and there are not obvious bad breaks which means that there are not abnormal compaction due to denudation(there is also the presence that the depth of new burial thickness is deeper than the depth of denudation thickness).Curves extend to surface, which Wu27 well acoustic curve cross over 182.4μs /ft, Wu17 well acoustic curve cross over 182.9μs /ft.Both is close to the theoretical value on the surface, which means layers were buried by normal pressure and great denudation didn't bring about[3-6].

Characteristics of sandstone physical property varied with depth in study area

The trend of porosity of sandstone in the study area is very obvious, and there is no obvious fault. The measured data lacks of shallow strata data (Qingyuangang group and the upper strata), if the trend extends up, the trend line and the surface intersect at about 40%, close to the surface of the surface sandstone porosity theoretical value. This curve represents the layer depth nowadays of the research area, that is the historical maximum buried depth, which from the data cannot reflect the erosion process information.

The change rules of vitrinite reflectance varied with buried depth in the study area

The vitrinite reflectance (Ro) is a widely accepted and widely index which is applied to degree of organic metamorphism. Organic material in source rocks is the result of the interaction of temperature and time. If in the process of organic matter burying there was large scale uplift and erosion process (historical buried depth is greater than current burial depth), vitrinite reflectance curve will deviate from Ro- depth relationships curve in the normal burial case.

From the Ro-depth relationship curve, in the semi logarithmic coordinates Ro and depth is linear and not obvious fault. Curves extend to the surface, close to 0.2% (vitrinite reflectance of the theoretical surface environment in the sediments is 0.2%), showing that in this figure Ro-depth curves have the typical characteristics of no erosion of burying normally.

Reflectance signatures of seismic cross section in the study area

The T_{22} is the border and above T_{22} seismic reflection axis is parallel to the reflection, between the layers (T_2, T_1, T_{04}) which is conformity (or disconformity) and toplap and truncation are less. Under T_{22} the layer deeper buries, more chaotic seismic reflects. T_{23} is the interface between Nantun Fm, 1st section and K_1n_2 which from the view of the distribution of layers is conformable contact.T_3 is the interface between Tongbomiao group and Nantun group, reflection between T_3 and T_5 is messy, which is not easy to distinguish the contact relationship of strata.

In the T_{22} interface, the reflection phase axis has a progradation structure feature, and the local area there is truncation. The discrimination between the progradation and the truncation can be distinguished by the contact relationship between the phase axis and the sequence boundary. The progradation structure phase axis and interface are gradient angular contact and truncation and interface are in direct contact of large angle. The eastern slope zone in the study area can be identified by truncation, reflecting the T_{22} level of the eastern slope zone is denudation. From the point of view of the seismic event rules, the denudation amount is not large, generally only 3-4 phase axises.

III. UTILIZE FORMATION TENDENCY METHODS TO RESTORE THE PLANE DENUDATION AMOUNT

The above method is suitable for the analysis of the amount of denudation in the profile, in order to calculate the amount of denudation in the plane, and it is necessary to make a quantitative analysis of the development trend of the plane layers. By numerical method, calculate and compare with the spatial variation law of the stratum thickness of the standard layer and the target layer, and calculate the distribution of the plane denudation quantity.

Nantun Fm, 1st section (T_3-T_{23}) is located under K_1n_2. T_{23} had no obvious denudation in the region while the top of K_1n_2 (T_{22}) in the seismic section has truncation, indicating that there are certain denudation processes. Nantun Fm, 1st section and K_1n_2 in the basin subsidence / formation sedimentary period are in the same tectonic environment and adopt the thickness of Nantun Fm, 1st section, which as a reference layer of K_1n_2 is reasonable.

The numerical method is used to calculate the change trend of the thickness of Nantun Fm, 1st section. First, get the plane distribution map of Nantun Fm, 1st section via formation thickness flattening method. Then calculate the change trend of thickness on the thickness distribution map, and use the angle to represent. The formula for calculating the change ratio of thickness ST:

$$S_T = \frac{360}{2\pi} \arctan \left[\left(\frac{\partial z}{\partial x} \right)^2 + \left(\frac{\partial z}{\partial y} \right)^2 \right]^{\frac{1}{2}} \qquad 5\text{-}5$$

The trend of formation thickness of Nantun Fm, 1st section and K_1n_2 is very close. In Wudong slope area thickness of Nantun Fm, 1st section and the K_1n_2 change slowly. Most areas are 0-5 degrees, locally 5 to 10 degrees. In Wunan sub depression area and Wuxi area local thickness change rate is high. Thickness change rate in the same location subtracts each other, and counts difference values. Data points of thickness variation rate of difference value of two sets of strata in the same location are in the range of 0 to 5 degrees (accounted for 77% of the total).

Select the datum that difference values variance ratio of the strata is less than 5 degrees in Nantun Fm, 1st section and the K_1n_2 to count (the two have the datum which have the similar variation trend), and get the average thickness 221.28m of the K_1n_2 and standard deviation is 151.8, the average thickness of Nantun Fm,1st section is 219.2m and standard deviation for 127.8. After the standardization of the datum of two layers, eliminate the influence of the thickness, representing the various trend respectively [7-8].

According to the preamble, the K_1n_2 in the normal the burial condition and Nantun Fm, 1st section should have the same the trend of thickness variation. Therefore, adopt the chart of the trend of thickness variation and statistical values of thickness of the K_1n_2. (counted by the regions where Nantun Fm, 1st section and K_1n_2 have the similar trend of the thickness). Use statistical values to restore and calculate the thickness of the K_1n_2 when not being denuded. The original thickness of the K_1n_2 subtracts present thickness, and the distribution of the amount of denudation in the K_1n_2 (Fig. 1) is obtained. The denudation thickness of K_1n_2 is 0-100m, which denudation area of 0-50m is relatively large, denudation area mainly distributes in Wudong slope zone, which this point and seismic events axial truncation are consistent. Because absolute value of denudation amount is smaller, according to the depth of Nantun group, the present buried depth is far higher than the historical depth, the effects of denudation on degree of organic metamorphism and reservoir-quality evolution can be neglected.

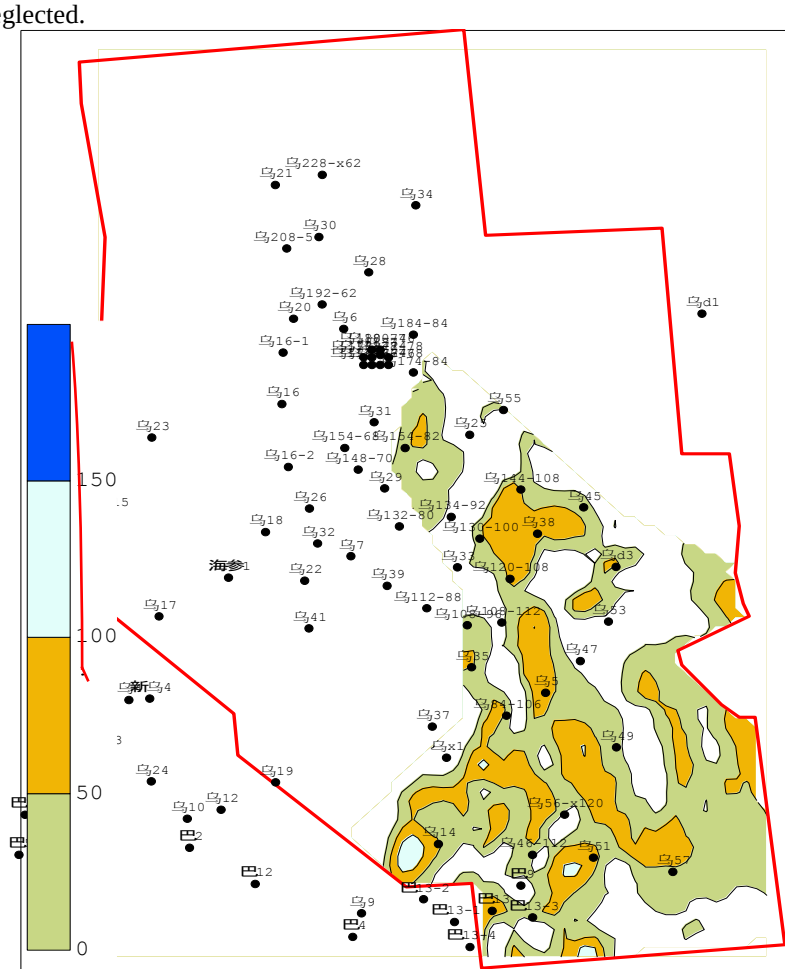


Fig.1 Plane distribution of erosion amount K_1n_2 in the the south of Wuerxun depression

IV. THE ANALYSIS OF PALAEOGEOMORPHOLOGY

On the basis of geological work, create the fundamental perception of palaeogeomorphology of the study area. Via special software three-dimensional terrain simulation Vue reappear the ancient landform of geological history.

Hailar basin experienced from the stage of the residual basin which filled and levelled up and made up in the mountains to the faulted period ,fault-to-depression transforming stage, depression phase developed by active rift basin in the later stage that is evolutions of a series of prototype basins .Deformation characteristics of basin can be divided into overall 1 (T_5), 3 (T_3), circle 5 (T_{23}-$_1$) and T_{04} three first-order tectonic sequences which represents three major tectonic basin evolution stages, the period that experienced 6 main deformation phases, namely: border3- border4, border 4- border5 , border5-border6, border6-border7, T_1-T_{04} and 7-6 since T_{04}.

According to the current situation of the data, the three periods were selected to analyze the characteristics of the ancient landform:

T_5: The early primitive stage of basin development.

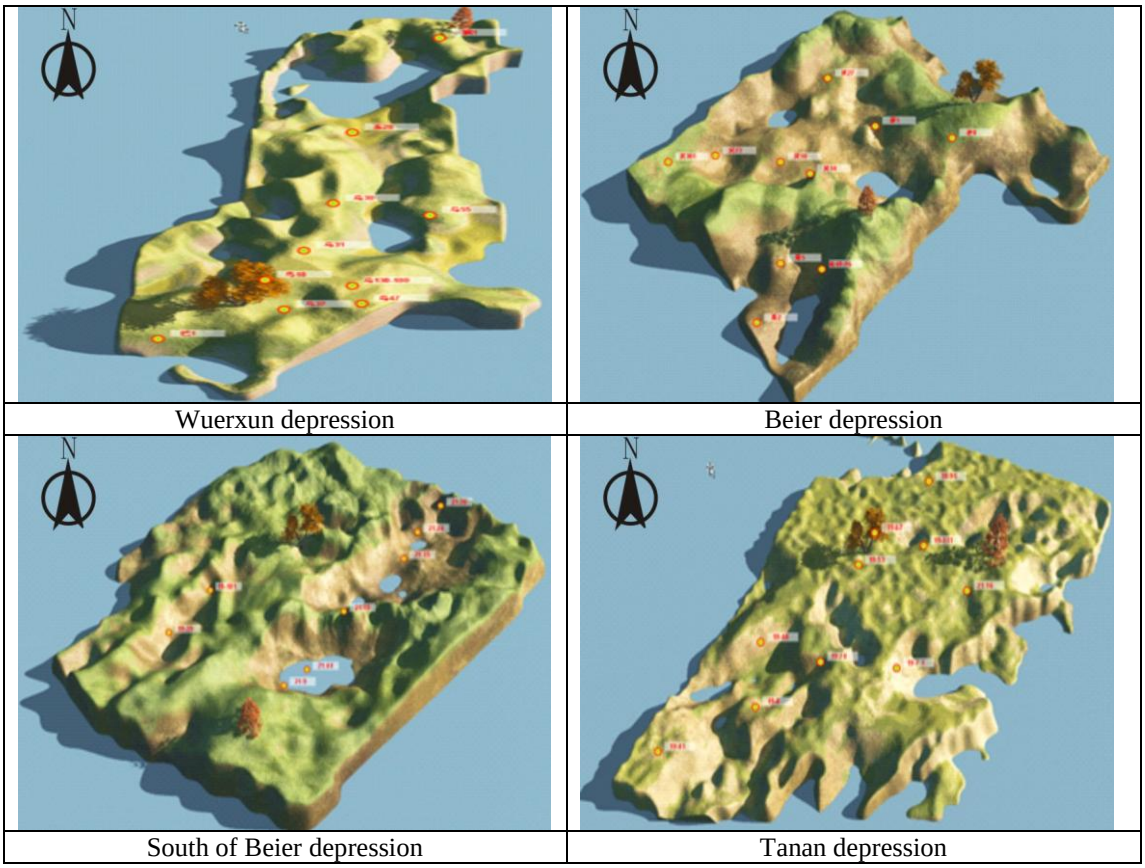
T_3: Top boundary of Tongbomiao group, the stage when passive rift basin starts to develop.

T_{23}: Top boundary of Nantun Fm, 1st section, the stage when active rift basin starts to develop.

T_{22}: Top boundary of Nantun group, the stage when fault-to-depression transforming starts to develop.

Simulation results of palaeogeomorphology characteristics of each depression at the sedimentary end of Tongbomiao group

The time belonged to the early stage where Hailar Basin developed. The basin was uplifted as a whole, the palaeohigh of basement rock exposed on the surface and denudes and region overall was smooth, had small fluctuations. The lake water on the basin was shallow and the area was small (Fig. 2).



Wuerxun depression | Beier depression

South of Beier depression | Tanan depression

Fig.2 Simulation results of palaeogeomorphology characteristics at the sedimentary end of Tongbomiao group

The north of Wuerxun depression had the distribution subtle large area of lakes. The south of Wuerxun had two small lakes, Surface relief in the east of Wuerxun was low, Bayantala had the local lake. The central region of Wuerxun was higher. Most of the area surfaces or buried very shallowly.

Baer depression in North and south was highlands. The middle of Beier surfaced and had only distribution of local lake, most areas buried very shallowly and exposed on the surface.

In the south of Beier depression only the east of secondary depression had shallow water, the rest of areas including the west of secondary depression and the central uplift exposed on the surface and was weathered and denuded.

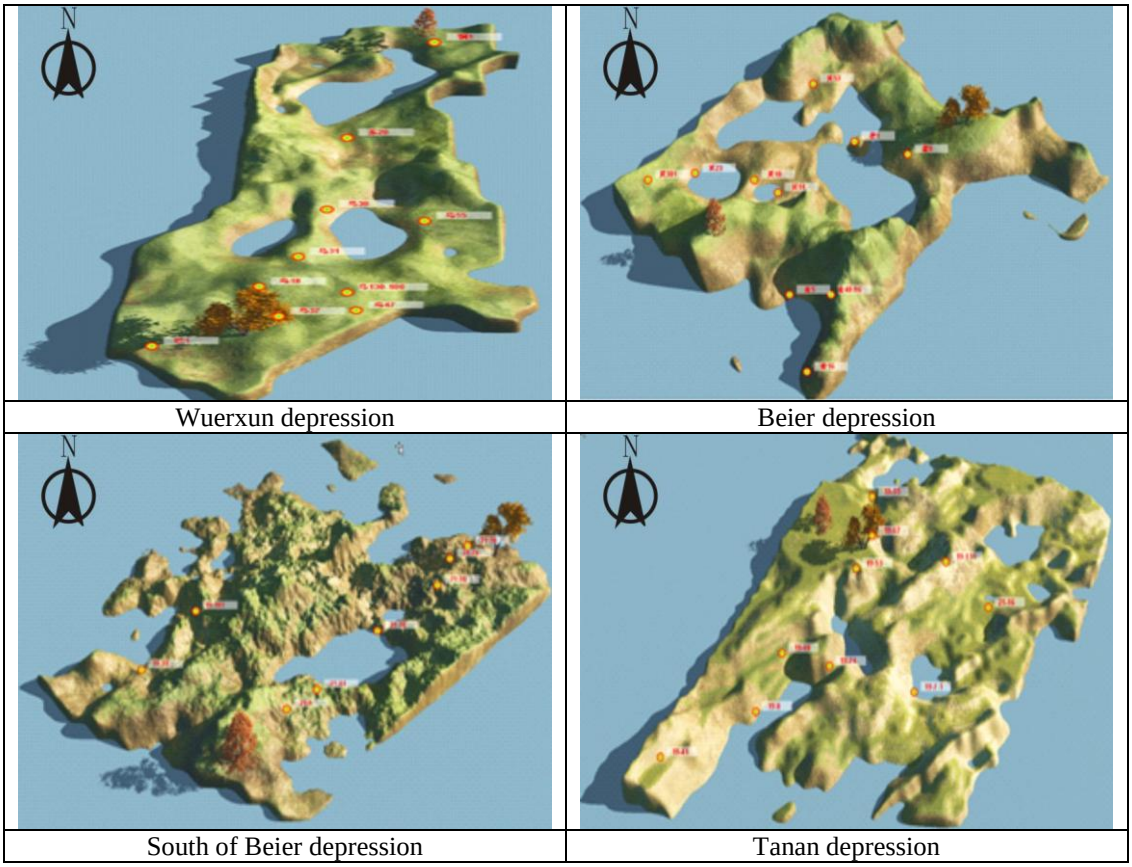
Tanan depression in the east and south had local water, the rest of areas buried shallowly or exposed on the surface. The whole area height difference was not large, relatively flat.

The elevation of the south and east of Tanan depression became shallow, most areas was covered with water, and the elevation of the northwest and north was slightly higher. The whole terrain height difference was not large.

The simulation results of the palaeogeomorphology characteristics at the sedimentary end of Nantun group 1 Member (T_{23})

The whole period of Haita basin water expanded, height difference increased, the main depressions had been formed (Figure 3).

In the south and north of Wuerxun secondary depression lake formed, surface relief in the east of Wuerxun was lower. The area of Bayantala was high and bedrock outcrop on the surface or shallowly buried. Highlands exposes beside the depression, especially south and north of Wuerxun.



Wuerxun depression	Beier depression
South of Beier depression	Tanan depression

Fig.3 The simulation results of the palaeogeomorphology characteristics at the sedimentary end of Nantun group 1 Member (T_{23})

In the middle of the Baer depression, the water area enlarges, and the highlands distributed around the depression. The middle of Beier had higher terrain.

The central uplift belt in the south of Beier depression uplifted, water area in the east and west of Wuerxun secondary depression expanded respectively like the sheet.

The simulation results of the palaeogeomorphology characteristics at the sedimentary end of Nantun group (T_{22})

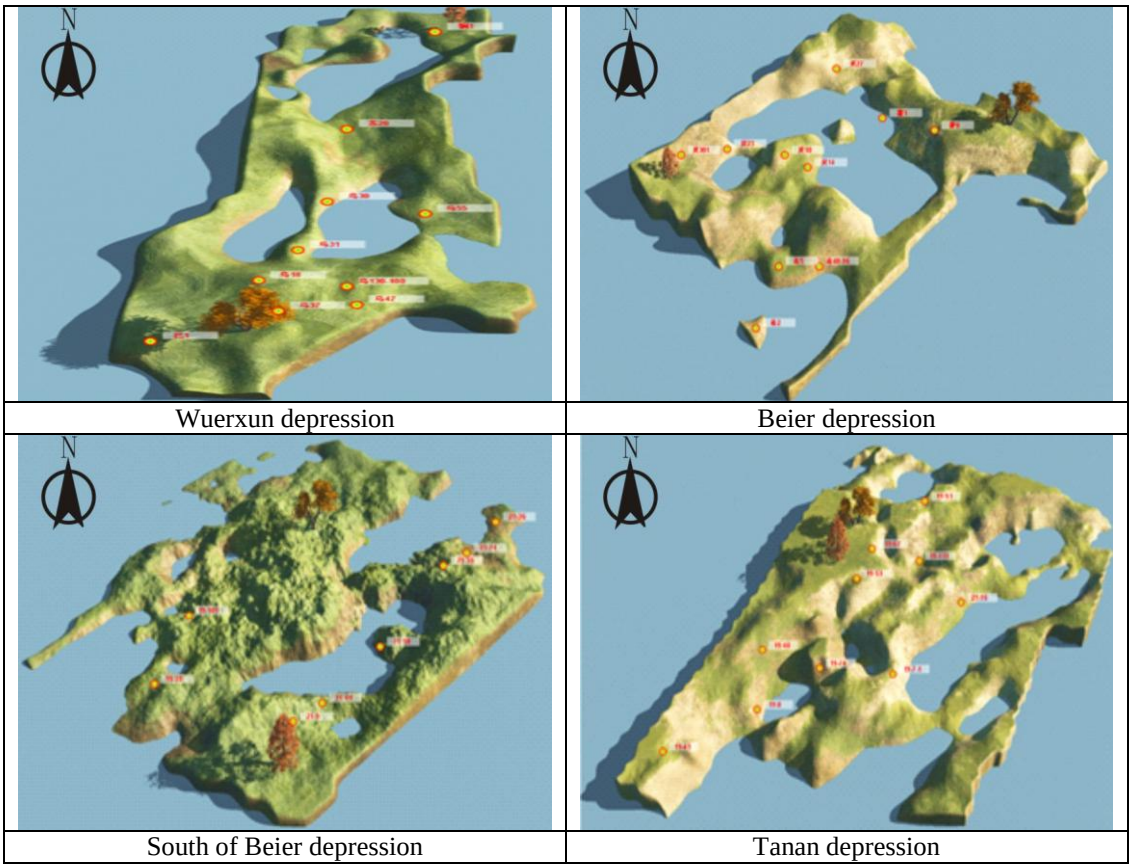
In this period, the basin was transformed from the fault depression to the depression, and most of the depressions had been formed. The edge of the depression was shallow water area or exposed on the surface (Figure 4).

Wuerxun depression: There are lakes in the south and north of Wuerxun depression and highlands around it.

Beier depression, central water area expands unbrokenly. The middle of Beier depression dipped and the water was deep. In the southern and northeastern highlands exposed.

The south of Beier depression, the central uplift belt uplifted, the water area of the east and west of secondary depression expanded respectively like the sheet.

Tanan depression, elevation in the south and east became shallow, most areas was covered with water, had slightly higher elevation in north and west.



Wuerxun depression	Beier depression
South of Beier depression	Tanan depression

Fig.4 The simulation results of the palaeogeomorphology characteristics at the sedimentary end of Nantun group (T_{22})

V. CONCLUSION

1 At the sedimentary end of Tongbomiao group (T_3) which belongs to the early stage when the Haita basin developed, the basin was uplifted overall, the palaeohigh of bedrock exposed on the surface and then was denuded, region overall was smooth and had small fluctuations. The depth of lake of the basin was shallow and the area was small. The north secondary depression in the Wuerxun depression distributes larger area of lakes. The south of Wuerxun depression has two small lakes. The terrain the east of Wuerxun depression is low. Bayantala has the local lake. The terrain the middle of Wuerxun is higher. Most of the area surfaces or buries very shallowly. The north and south of Baer depression distributes the highlands. The middle of Baer depression surfaces and only distributes the local lakes, most of the area buries very lowerly or exposes on the earth's surface. In south of Beier depression only the east of secondary depression distributes shallow water, and the rest, including the west of secondary depression and the central uplift exposed on the earth's surface, which are weathered and denuded. Height difference of the whole area is not high and relatively flat. Elevation of the south and east of Tanan depression becomes shallow. Most areas are covered with water, elevation of the northwest and the north is slightly higher. Height difference of the whole terrain is not large.

2 At the sedimentary end of Nantun Fm, 1st section (T_{23}) throughout the period of water mass expanded, height difference increased, the main depressions have been formed. In the north and south of secondary Wuerxun depression lakes were formed. In the east of secondary Wuerxun depression terrain is low. In Bayantala terrain is high and the bedrock outcrop on the earth's surface or buried shallowly. Highlands exposed the periphery of depression, especially the periphery of south and north of Wuerxun encircling highlands. In the middle of the Baer depression, the area water mass enlarged unbrokenly. Highlands is distributed around the periphery of depression. The central area has higher terrain. Central uplift belt of the south of Beier depression uplifted. In the east and west of secondary depression the area of water mass expanded respectively like the sheet.

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