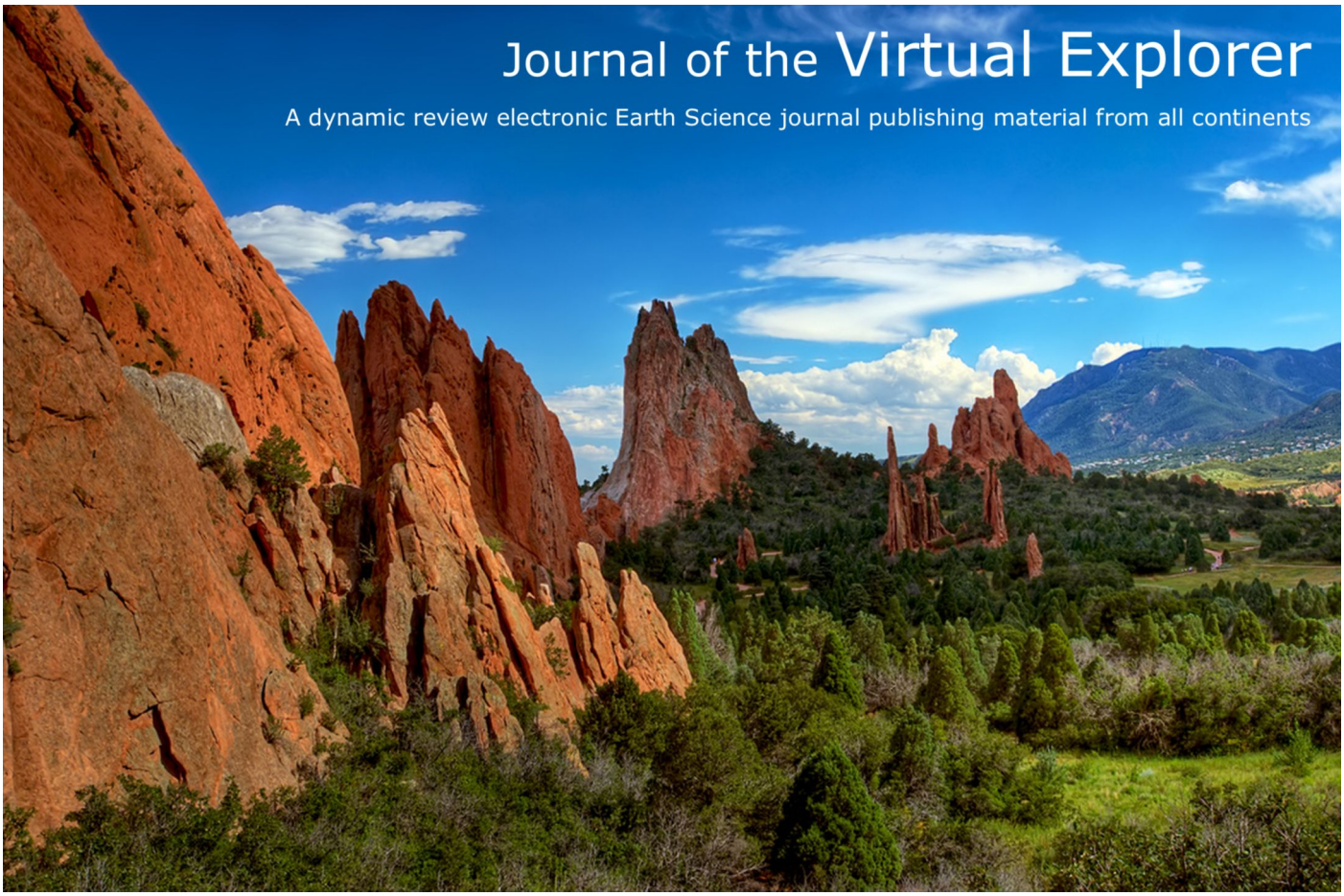

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Abstract: The Qaidam Basin in the western China is a major Meso-Cenozoic petroleum basin. This paper deals with the recovery of the sedimentary evolution history and distribution of the Paleogene Ganchaigou Formation in the North-West Qaidam basin on the basis of analysis of single-well and multi-crosswell profile sedimentary facies analysis. The result shows that period of E_{1+2} were the occurrence of Lake Basin stage. Most of the region was braided-river and over-bank deposit. There was a small-scale orogeny in early E_3^1, and the deposition system can be summarized as alluvial fan, braided river delta and shore-shallow lacus sedimentary system. After the orogeny, the lake area began to expand. During period of E_3^2, the climate turned into semi-arid from arid. Freshwater recharge capacity increased, the lake expanded and the water level rose. The lake basin developed into its flourishing period. Fluvial facies and delta facies retrograded to the northeast. The area of lacustrine sedimentation turned into its maximum in period of E_3^2, the lake area further expanded and the depth of water further increased. The deposition center was located in the Nanyishan and Xiaoliangshan region.

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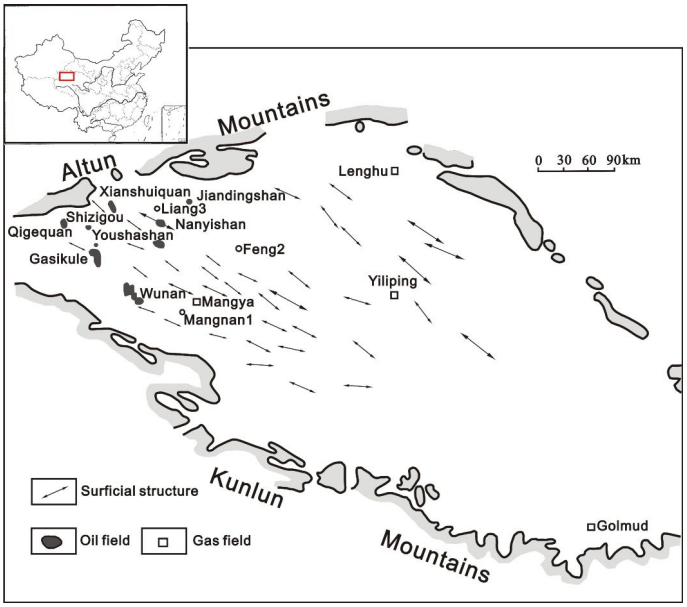
Introduction

Qaidam basin, located in Qinghai Province, is on the northern margin of Qinghai-Tibet Plateau. It has been known as one of the three major interior basins besides Tarim Basin and Junggar Basin. Qaidam Basin is a component of the Xiyu Plate, surrounded by the mountain ranges and discordogenic faults of Qilian, Kunlun and Altun. Qaidam Basin belongs to Tarim-Sino Korea Plate. With neighboring plates and crustal blocks, it experienced continental dispersion, ocean crust subduction, arc-arc or arc-continent collision accretion during Palaeozoic Era, and within-plate deformational supraposition in Meso-cenozoic. On the basis of partial fault subsidence in Mesozoic, the Cenozoic sedimentary structure evolvement experienced fault sag transition, fault sag and inverted fold. Previous research has made great contribution in exploring and researching the sedimentary facies of Tertiary in North-West Qaidam Basin (Dang, *et al.*, 2004; Jin, *et al.*, 2002; Yang, *et al.*, 2003; Wu, *et al.*, 2003; Gao, *et al.*, 2003; Wang, *et al.*, 2002). However, there were relatively few discussions about the classification of the sedimentary microfacies and subfacies (Tian, 1996; Huang, *et al.*, 1993; Liu, *et al.*, 2009; Li, *et al.*, 2009). This paper aimed at the determination of plane distribution of facies and sedimentary evolution model.

Geological background

Fig. 1 shows the current Mechanical Mechanisms diagram of north-west Qaidam basin. Located on the binding of Ancient Asian and Tethys-Himalayan tectonic domains, Qaidam Baisin suffered great complicated tectonic stress which resulted in significant uplifted structure.

Figure 1. The Tectonic mechanical mechanism of northwest Qaidam



The action of NS compressional stress has been the major Mechanism and Dynamic Sources of most tectonic uplifts in the region. Meanwhile, the compression stress produced two sets of shear stress, of which one was parallel to the Altun Tagh fault. These two sets of shear stress made the tectonic uplifts in the west region take a clockwise rotation. It formed a series of "S type" anticlines there. Moreover, the Tertiary uplift which formed by the actions of NS compressional stress is the main oil-bearing structure within the region (Sun, 2004; Deng, *et al.*, 1998; Dai, *et al.*, 2000).

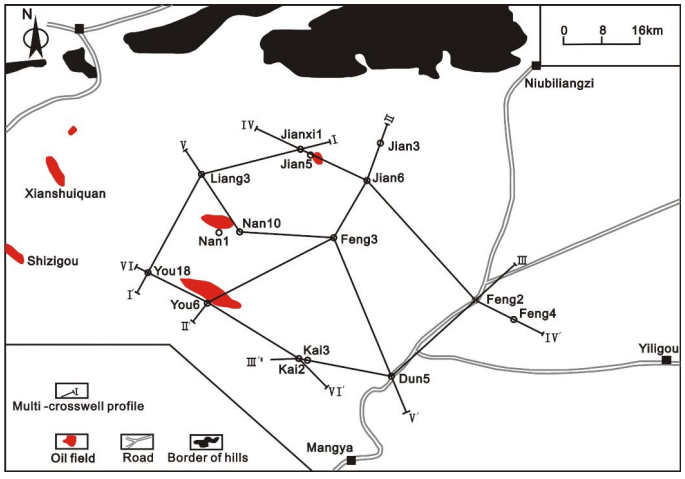
The north-west region was the major depressed area in Oligocene-Pliocene Epoch of Qaidam Basin, and it is the main current petroleum province of the basin. The Tertiary strata of Qaidam basin includes Lulehe Formation (E_{1+2}), Lower Ganchaigou Formation (E_3), Upper Ganchaigou Formation (N), Lower Youshashan Formation (N_1^2), Upper Youshashan Formation (N_2^2), and Shizigou Formation (N_3^2) from bottom to top (Liu, 2003). Previous research has roughly classified the Tertiary sedimentary facies of the North-West Qaidam Basin, but some are not quite exact, especially the classification of sedimentary microfacies. Through research, the thesis systematically analyzed the sedimentary microfacies of period E_{1+2}, $E_3^1$and E_3^2, and then established the distribution of sedimentary microfacies and the evolution of sequence depositional facies.

Single-well Sedimentary Facies Division of Typical Wells

The classfications of sedimentary facies for the following 8 single wells has been analyzed: Liang3 well, Jianxi1 well, Jian3 well, Jian5 well, Jian6 well, You6 well, Feng2 well and Nan10 well. The single well sedimentary microfacies of Nan10 well, Jian3 well in the period of E_{1+2}, E_3^1, E_3^2 as well as that of You6 well and Feng2 well in the period of E_3^1, E_3^2 will be discussed in more detail.

Nan10 well in the depression region of western Qaidam Basin is to the south of Nanyishan tectonic belt (Fig. 2). 3158m-4255m is for E_3^2 Formation, 4255m-4566m is for period of E_3^1, and 4566m is the top of the E_{1+2} Formation, bottom not reached. The lithology of this region, which consists of mainly grey and dark grey calcic mudstone, including some mudstone colored brownish grey, some sandy shale and calcisiltie, was shallow lacus facies deposit. In period of E_3^1 (4566m-4255m), Nan10 well mainly developed braided-river delta plain subfacies which can be divided into distributary channel microfacies and interdistributary bay microfacies(Liu, *et al.*, 2009; Luo, *et al.*, 2009; Zhang, *et al.*, 2006), only sedimentated braided-river delta front subfacies on the bottom. It developed a large lacustrine sedimentation in period E_3^2 around Nan10 well, so Nan10 well developed the subfacies of braided-river delta front, braided-river delta plain and shallow lacus facies from bottom to top.

Figure 2. The Location of Multi-Crosswell Profile in the North-West Qaidam Basin



Jian3 well is located on the top of Jianbei buried structure. The section of 1085m-2376m is for E_3^2 Formation, 2076m-3014m is for E_3^1 Formation, and E_{1+2} Formation is under 3014m, bottom not reached. It was subfacies of meandering riverbed that sedimented in the period of E_{1+2}. The E_{1+2} period sedimentated the subfacies of meandering riverbed in the basin, where the lithology are primarily purple and dark purple mudstone, mingled with grey sandy limestone, calcareous sandstone and grayish green mudstone. According to lithology, it can be divided into fluvial channel microfacies, lake flood plain microfacies and fluviatile flood plain sedimentation microfacies. Jian3 well mainly developed braided-river delta plain subfacies during period of E_3^1. The lithology were mainly siltstone, fine sandstone, pebbled sandstone and grey conglomerate, followed by purple mudstone and sandy shale, and a small amount of grey green mudstone. The bottom of Jian3 well is a set of alluvial fan gravel layer which is about 8 meters thick (Zhang, 2007; Wang, *et al.*, 2007). E_3^1 Formation developed four positive cycles of sedimentation from bottom to top and all of them were composed by distributary channel sedimentation and interchannel or interdistributary bay sedimentation. The lithology of E_3^2 (1085m-2376m) section in this well are mainly mudstone and lime mudstone colored grey, grey green, brownish red and mulberry, mixed with superior dark grey limestone, muddy limestone and grey siltstone and fine sandstone. The well developed braided-river delta front subfacies (2376m-2220m) and shallow lacus subfacies (2220m-1085m) . The former one includes interdistributary bay underwater mingled together with sand sheet subfacies and mouth bar subfacies. The sedimentary facies of Jian3 well changed significantly from period of E_{1+2} to E_3^2. There sedimentated mainly alluvial fan in the period of E_{1+2}, which turned to braided-river delta plain sedimentation when reached E_3^1 Formation. It developed braided-river delta front and shallow lake deposit during period of E_3^2.

You6 well is situated in the south wing of Youquanzi structure in Qaidam Basin. The drilled well is 4616m in depth. E_3^2 Formation covers 4263.5m-2877m and period of E_3^1 Formation is beneath 4263.5m. Period of E_3^1 was mainly braided-river delta plain facies which can be further divided into predelta subfacies, braided-river delta front subfacies and braided-river delta plain subfacies. The lithologic character of E_3^2 Formation is light grey siltstone,calcareous siltstone and limy siltstone, which presented non-isopach with dark grey and grey mudstone. The siltstone is generally 1.5m-3m thick. The

calcareous sandstone is 1.5m-2m thick and the thickest is 3m. The sedimentary facies of period of E_3^2 were shallow lacus facies and braided-river delta front facies.

Feng2 well is located in Mangya depression of Qaidam Basin, the axial of Dafengshan fold tectonic. The depth of E_3^2 Formation is 3000m-4410m, E_3^1 Formation is below 4410m. E_3^1 Formation of Feng2 well mainly distributed with alluvial fan deposits, followed by fluvial channel subfacies and flood plain subfacies. The lithologic character of Feng2 well during E_3^2 was mainly alternate strata about crimson, fuscous and grey mudstone, brown and oyster grey siltstone, and calcareous sandstone. Gamma-ray curve was seriously serrated denticle. According to these characteristics, it was defined as flood plain sedimentation. The sedimentary facies of Feng2 well developed from fluvial channel deposit subfacies of alluvial fan deposit to flood plain subfacies between period of E_3^1 and E_3^2.

Sedimentary Facies of Multi-Crosswell Profile Analysis

According to the analysis of the sedimentary facies of individual well, fluvial channel deposit of meandering stream developed in the research area during period of E_{1+2}. The sedimentation types varied when came to period of E_3^1, and they were mainly lacustrine deposit, delta facies of anastomosing stream and alluvial fan facies. Lacustrine sedimentation extensively distributed in period of E_3^2. The clastic reservoir condition in E_3^1 period was better than E_3^2 and E_{1+2}[1]. 6 Multi-crosswell profiles were chosen in the North-West Qaidam Basin, basically covered most research areas (Fig. 2). The following discussion will analyze the sedimentary facies distribution of each reservoir according to multi-crosswell profile.

The multi-crosswell profiles I-I' is nearly NE-SW trending, crossing You18, Liang3 and Jianxi1 wells. The upper section of this multi-crosswell is shallow lacus facies, gradually changed to braided-river delta front and plain subfacies, presenting obvious retrograding sequence. It illustrates that the lake area has been expanding. The lake depth of Xiaoliangshan area is the bottommost.

The multi-crosswell profile II-II' is nearly NE-SW trending, crossing You6, Feng3, Jian6 and Jian3 wells. It was bank lake sedimentary facies in the upper E_3^1 section of You6 well and Jian6 well. And the top E_3^1 section of Jian3 well was braided-river and floodplain deposits inserted into braided-river delta plain deposit. The sedimentary sequence was braided-river delta plain subfacies, delta front subfacies and bank lake facies from top to bottom. We could draw a conclusion that the provenance was in the northeast from sedimentary facies distribution.

The multi-crosswell profile III-III' is nearly NEE-SWW trending, crossing Kai2, Kai3, Dun5 and Feng2 wells. Lacustrine sedimentation has been distributed to the southwest of Dun5 well, and the northeast part mainly spreaded braided-river delta facies sedimentation. When reached Feng2 well, the braided channel and floodplain facies could be seen. The profile illustrated that it displayed retrograding sequence which transited from braided-river delta plain subfacies to delta front subfacies, bank lake facies, and coastal-shallow lake subfacies in the vertical. It has been clarified that the lake was expanding to the northeast.

Multi-crosswell V--V' is nearly NW-SE trending crossing Lian3, Nan10, Feng3 and Dun 5 four wells. Coastal shallow and semi-deep lake facies were near Liang3 well. There were mainly bank lake facies around Dun5 well while the central part was braided-river delta facies, which made a deposition sequence not that obvious.

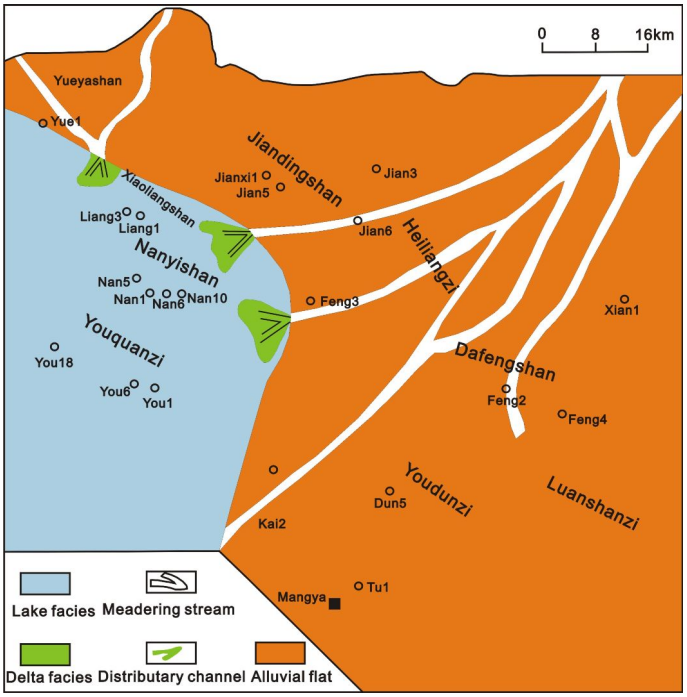
Crossing You18, You6 and Kai2 wells, Multi-crosswell VI--VI' is NW –SE trending. It distributed braided-river delta plain subfacies, delta front facies, bank lake subfacies and coastal-shallow lake subfacies from bottom to top, presenting a retrogradation sequence.

Plane Sedimentary Facies Distribution

Sedimentary Facies Distribution for Period of E_{1+2}

During E_{1+2}, most area of the research region was composed of red and varicoloured fluvial facies clastic rock which was braided-river sedimentation and flood plain sedimentation. Grey microclasticrock could only be found in Xiaoliangshan, Nanyishan, Youquanzi area and Shizigou area. Those places were small-size lake and delta facies (Fig. 3).

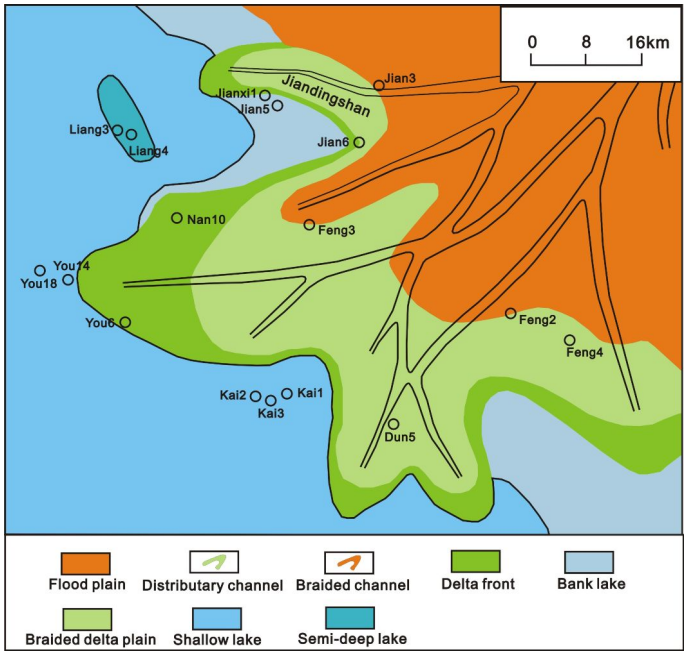
Figure 3. The Sedimentary Facies distribution of Period E_{1+2}



Sedimentary Facies Distribution of Period E_3^1

The research area developed braided-river sedimentation, braided-river delta sedimentation and lacustrine sedimentation in turn from northeast to southwest during period of E_3^1, and the lake basin was obviously enlarged (Fig. 4). Braided-river sedimentation in this region mainly consisted of braided channel subfacies and floodplain subfacies. Delta facies included delta plain subfacies and delta front subfacies. Lake facies was divided into subfacies of bank lake, coasta-shallow lake and semi-deep lake. That basically inherited the river facies sedimentation features of period E_{1+2} and mainly developed braided channel sedimentation and floodplain sedimentation in Dafengshan and Heiliangzi area.

Figure 4. The Sedimentary Facies distribution of Period E_3^1



Grey-dark grey lacustrine facies microclasticrock developed in the west part of Xiaoliangshan. Delta facies was basically in the eastern area. Youquanzi area mainly developed delta front subfacies. It was mainly Delta plain subfacies that overspreaded in Jiandingshan, south part of Nanyishan, Huanggualiang and Youdunzi area.

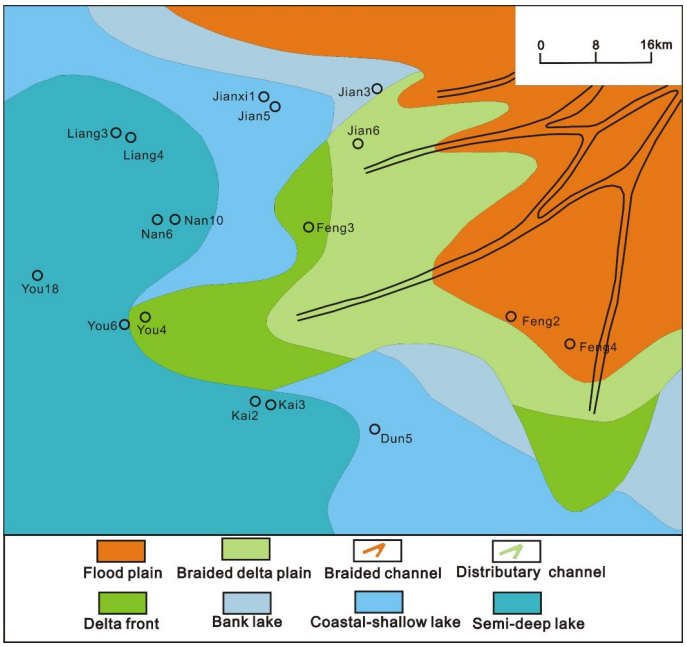
According to the analysis above, the lake was mainly distributed in the west half region during period E_3^1, and the area was significantly larger than that of E_{1+2} period. The depocenter was located in Xiaoliangshan area, and the delta lobes were mainly in Jiandingshan, Youquanzi and Youdunzi area. River-floodplain sedimentation was mainly situated in Dafengshan and Heiliangzi area. However, judging from the single well facies of Jian3 and Nan10, a small-scale orogeny happened in the northeast part of this region during early E_3^1 period. It developed a set of alluvial fan conglomerate strata about 8 meters thick on the bottom of E_3^1 Formation in Jian3 well. In early period of E_3^1, a bottom-up progradational sequence of braided-river delta front subfacies and plain subfacies in Nan10 well were established, and there was a momentary lake regression. The sedimentation system of period E_3^1 can be summarized as alluvial fan, braided river delta and shore-shallow lacus sedimentation.

Sedimentary Facies Distribution of Period E_3^2

The overall sedimentary facies distribution did not change obviously when developed into period of E_3^2

(Fig. 5). The area of lacustrine mudstone further extended and the sedimentary system of river and delta retreated to northeast. The amount of coarse fragments reduced in Jiandingshan, Heiliangzi, south of Dafengshan and Nanyishan area. Delta plain subfacies turned into bank lake subfacies in Jiandingshan area. Delta front subfacies turned into coastal-shallow lake subfacies in south of Nanyishan. And in Heiliangzi area, the Floodplain subfacies translated into delta plain subfacies.

Figure 5. The Sedimentary Facies distribution of Period E_3^2



According to the analysis above, E_3^2 was the biggest lake flooding period when the area of lacus basin further expanded and the water depth further deepened. The semi-deep lake sedimentation obviously increased, and the deposit center located in Nanyishan and Xiaoliangshan areas. The sedimentary system of period E_3^2 could be summarized as alluvial fan-braided-river delta plain-bank lake subfacies, coastal-shallow lake subfacies and semi-deep lake subfacies.

Discussions and Conclusions

According to the collected data of single wells, cross-well profile anylisis, as well as the previous research, the lake basin in western Qaidam Basin experienced two stages of occurrence and development from period of E_{1+2} to E_3^1. Period of E_{1+2} was when the arid climate and strong evaporation engendered a shallow lake and brackish water flood plain sedimentation in many places. But there was small lake deposit in Xiaoliangshan, Youquanzi, Honggouzi and Nanyishan area. In period of early E_3^1, a small-scale orogeny took place in northeast of this region, which developed a set of alluvial fan conglomerate about 8 meters thick on the bottom of E_3^1 section in Jian3 well, and a instantaneous lake regression in Nan10 well where deposited the progradational sequence of braided-river delta front subfacies and plain subfacies from bottom to top. The lake basin began to extend after the orogeny. Lacustrine deposit developed largely in Youquanzi, Xiaoliangshan and its northwest area while it developed fluvial deposit and delta deposit in the east region.

The climate turned semi-arid when entering period of E_3^2, and the lake basin developed into its floruit where the water supply increased, the lake expanded and the water level rose. The fluvial and delta facies retrograded to the northeast and the lacustrine sedimentary area reached its largest.

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