文章编号: 1000-0550(1999)03-0403-06

鄂尔多斯盆地中部石炭—二叠系沉积相带与砂体展布

魏红红[1] 彭惠群[2] 李静群[2] 谢正温[2] 漆雕良[2]
1(西北大学地质系 西安 710069)
2(长庆石油勘探局井下技术作业处 甘肃庆阳 745113)

摘 要 鄂尔多斯盆地石炭—二叠系广泛发育潮坪、三角洲、湖泊沉积。中上石炭统本溪组和太原组以潮坪相为主,下二叠统山西组沉积初期以全盆地范围广布三角洲平原沉积为特征,山西组沉积后期到下石盒子组沉积期,南北差异特征明显,北部发育三角洲平原,南部发育三角洲前缘。上二叠统石盒子组和石千峰组发育湖泊沉积。三角洲平原分流河道和三角洲前缘水下分流河道砂体在盆地内最为发育,是该区的主体储集砂体。潮坪砂坝和三角洲前缘指状砂坝也是较有利的储集体。其纵向发育和横向展布是今后气田勘探的一个重要研究课题。

关键词 鄂尔多斯盆地中部 石炭系 二叠系 沉积相 砂体展布
第一作者简介 魏红红 女 1973年出生 硕士生 沉积学
中图分类号 P588.2 文献标识码 A

1 区域地质背景

鄂尔多斯盆地位于华北克拉通西缘,北跨乌兰格尔基岩凸起与河套盆地为邻,南越渭北挠褶带与渭河盆地相望,东接晋挠褶西带与吕梁隆起呼应,西经冲断构造与六盘山、银川盆地对峙,面积约 $2.5\times10^5\ km^2$[1]。

石炭纪时盆地以继承早古生代的构造格局为主,表现为南北隆、东西凹、中间有一鞍部。东西两凹的沉积幅度和构造活动性差异很大,在中石炭世呈明显的分割状态,仅在晚石炭世初期两凹的海水才与中间鞍部连通。西缘凹陷是早古生代剪切—张性裂谷基础上发育起来的,而东部凹陷是克拉通内坳陷。二叠纪后,由于南北两边缘的俯冲和碰撞造山,以及相应于南北方向上的收缩挤压作用,致使该区自二叠纪以后形成统一的克拉通拗陷,同时强化了克拉通内东西走向的次级隆起和凹陷,以及定边—吴堡区域东西向构造带的形成和发展。

在上述区域构造背景下,石炭—二叠纪沉积演变序列是从海相逐渐过渡为陆相。石炭纪时,海侵来自华北海和祁连海。以华北海海侵范围最大,向西达东经107°附近。西部拗陷海侵最早,开始于纳缪尔期,拗陷幅度大,发育泻湖沉积。东部拗陷海侵晚,开始于斯发期,拗陷幅度小,发育潮坪沉积[2]。南北向的中央隆起于晚石炭世开始接受沉积,以潮上带和潮间带发育为主。石炭系沉积之后,鄂尔多斯盆地及其周缘原有的隆拗格局逐渐消失,盆地西缘和北缘相继抬升,形成了统一的南陡北缓的向东开口的克拉通拗陷盆地,开始了二叠纪—中三叠世沉积,沉积相主要为三角洲和湖泊。古气候特征以炎热干旱为主,红层十分发育,仅早二叠世气候较为温暖潮湿,在山西组中发育煤层和煤线。

2 沉积相类型

划分沉积相的目的在于研究储集层的分布规律及其储集性能。对于一个沉积盆地某一地质时期沉积相的划分应该把地理位置、物源与成因结合起来,综合反映沉积相的分布范围、沉积环境和母岩性质。因此,沉积相应该是受同一水系或同一侵蚀域,受相同地质营力影响的沉积环境和沉积物的总合[3]。

本区石炭—二叠纪的沉积相类型主要有潮坪、三角洲和湖泊。

收稿日期: 1998-03-04 收修改稿日期: 1998-06-26

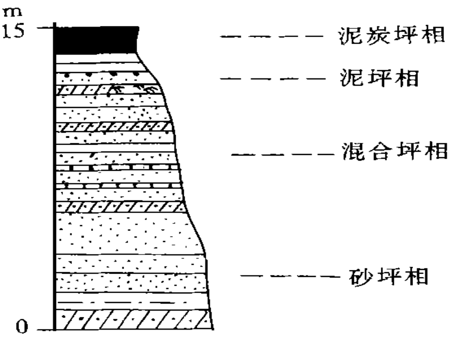

图 1 鄂尔多斯盆地中部上石炭统潮坪沉积层序
Fig. 1 Sedimentary sequence of Upper Carboniferous wadden in the central part of Ordos basin

2.1 潮坪相

主要发育于石炭系本溪组和太原组,主体由潮间带和潮上带沉积物组成。岩石类型以砂、粉砂和泥岩为主,并夹灰岩、根土岩和煤层。具多种潮汐成因的层理构造,如压扁层理、透镜状层理、波状层理和人字形交错层理,以及低角度板状交错层理、沙纹交错层理等。层面构造常见波痕、干裂和雨痕。含腕足类、三叶虫、苔藓虫、介形虫、珊瑚、棘皮类和植物和化石。根据沉积特征,可将本溪组和太原组中发育的潮坪相划分为砂坪、泥坪和砂泥混合坪(图1)。

砂坪主要由细粒石英砂岩组成,夹有粉砂岩及泥岩薄层,以压扁层理最为发育,此外还发育沙纹层理、双粘土层和板状收敛状交错层理等。含有植物化石碎片及炭屑。混合坪以发育条带状潮汐层理的细粒石英砂岩和泥岩为代表。其中潮汐砂泥岩交互层理极为发育,以条带状潮汐层理最典型,并发育生物扰动构造。泥坪主要由泥岩和页岩组成,并夹有透镜状粉砂岩和砂岩。以发育水平层理、透镜状潮汐层理,含植物化石碎片,具有生物扰动构造。常以煤层底板或顶板形式出现。本区的潮坪沉积一般具有向上变细的沉积层序,层序底部以砂坪开始,向上过渡为混合坪,顶部为泥坪,泥坪之上多发育泥炭坪,有煤层形成。

2.2 三角洲相

三角洲相在石炭系和二叠系均有分布,在二叠系山西组和下石盒子组最为发育。主要由三角洲平原和三角洲前缘两种亚相组成。三角洲前缘沉积层序下部由粉砂岩、泥岩组成、夹细砂岩薄层。发育水平层理、水平波状层理,沙纹层理。向上过渡为板状收敛状交错层理及沙纹层理中细粒石英砂岩、长石石英砂岩。交错层理细层倾向多具双向性,系前缘砂坝相沉积。层序中部过渡为分流间湾相的泥岩、粉砂岩。层序上部又过渡为前缘砂坝相中、粗粒砂岩。层序顶部发育了三角洲平原相沉积,为砂泥岩互层沉积[4]。发育槽状、板状交错层理及沙纹层理,含植物及淡水动物化石,见垂直虫孔和植物根(图2)。

2.3 湖泊相

主要见于二叠系上石盒子组。本区主要发育浅湖亚相沉积,以细砂岩、粉砂岩与泥岩互层为特征。常见水平层理、波状层理、沙纹交错层理及浪成对称波痕等。生物化石丰富,有鱼类、鳚鳃类、叶肢介及介形虫,并见植物化石碎片,水平虫迹十分常见。

3 沉积相与砂体展布

3.1 中石炭世本溪组沉积相与砂体展布

本溪组下部为盆地大面积分布的潮坪沉积,砂体分布局限,只在靖边以东发育几个零星分布的小型砂坝,且砂体厚度薄。在 S19 井一套砂岩厚度只有 5.4 m,在 S41 井一套砂岩厚度 4.9 m。

本溪组上部为陆表海清水与浑水的混合沉积,发育潮坪小型砂坝沉积。砂体厚度变化大,一般在 24.0~157.4 m 之间,单砂层厚度为 2~5 m,单砂体宽数百到千余米。仅在盆地东北角发育三角洲前缘相。砂体主要为水下分流河道沉积,呈北北东的长条状分布,北起 S201 井,南至 Q1 井。岩性主要为灰白色石英砂岩,石英含量达 95%以上,岩屑仅为 0.7%~5%,杂基 4%~24%,粒度变化大。粗—细粒。这种砂岩石英含量高、分选好、杂基低、压实程度弱、保存原生粒间余孔多,但微裂缝极不发育,连通性不好,渗透率低。因此这类纯孔隙型的砂岩体一般很少能形成好的天然气产层。

3.2 晚石炭世太原组沉积相带与砂体展布

晚石炭世太原组沉积初期海侵较本溪期为广,当时本区构造运动微弱,海底平缓,水动力条件较弱,物源供给少,为一套砂岩薄互层及粉晶生物碎屑灰岩组成的含煤建造。全区接受了一套以潮坪相和三角洲相为主的沉积。其中 S199—S177—S183—横山—Sh1 井一带继承了中石炭世浅水三角洲沉积的特征,以三角洲前缘相砂体沉积为主,而 S199—S176—S177 井一带和 S196—S183 井一带及 Sh2—S118—S151 井一带存在三条比较发育的砂体

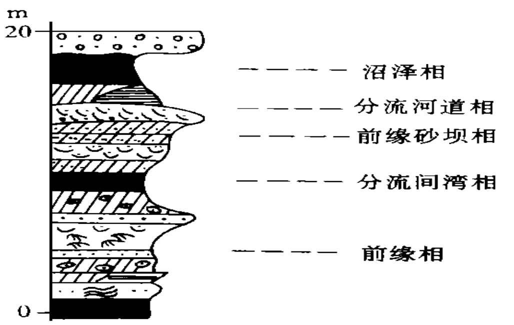

图 2　鄂尔多斯盆地中部下二叠统三角洲前缘沉积层序

Fig. 2　Sedimentary sequence of Lower Permian deltas front in the central part of Ordos basin

(图 3)。砂岩累计厚度 5 ~ 30 m。其中 Sh2—S118—S151 井一带的砂体次生溶蚀孔隙最为发育,又伴有微裂缝,形成了好的次生孔隙砂岩储层。在 S118井溶蚀孔隙度为2.50% ~5.50%,裂缝为 0.20% ~0.70%,平均孔隙度为 7.50%,渗透率为 $2\times10^{-3}\sim1.65\times10^{-3}\mu m^2$。潮坪砂体主要为小型砂坝,在靖边以南广泛发育。一般由 2 ~3 个砂体叠置而成,自下而上有向陆一侧迁移的趋势。单砂体厚 8 ~ 12 m,叠置复合砂体厚 30 ~ 50 m,砂体底平顶凸,靠陆一侧缓,靠海一侧陡,平面上呈串珠状。

太原组沉积后期,除盆地东北角有一小部分的三角洲前缘、水下分流河道沉积外,其余盆地内大范围地遍布潮坪相。东北部 Y24—S118—S201—Sh2 井水下分流河道砂体厚度大,一般厚度 20 ~ 60 m。潮坪的小型砂坝沉积砂体厚度一般仅有 4 ~ 12 m,并且主要夹在灰岩发育层段中,砂体分布范围十分局限,很难形成好的储集体。

3.3　早二叠世山西期沉积相带与砂体展布

至华力西旋回末期,秦岭海槽再度对挤,整个华北地台抬升,海水从鄂尔多斯东西两侧迅速退出,古地貌和古气候发生巨大变化,沉积范围较晚石炭世时有明显扩大。受古地形因素的影响,南北向沉积分异作用明显增强。在山西组沉积后期,南北差异沉降和相带分异更为明显,北部以三角洲平原为主,南部以三角洲前缘相为主。

山西组下部以三角洲平原在盆地内广泛发育为特征。沉积区水体浅,沉积范围广,沉积厚度小。三角洲形态为鸟足状,由数个沉积旋回的砂岩体叠合后呈现朵状。青阳岔和三岔渠以北,砂体较为发育,砂岩厚度 16 ~26 m。Y23—Y8 井砂体厚度 12 ~27 m。S24—S65 井砂体厚度 12 ~27 m。S198—S160

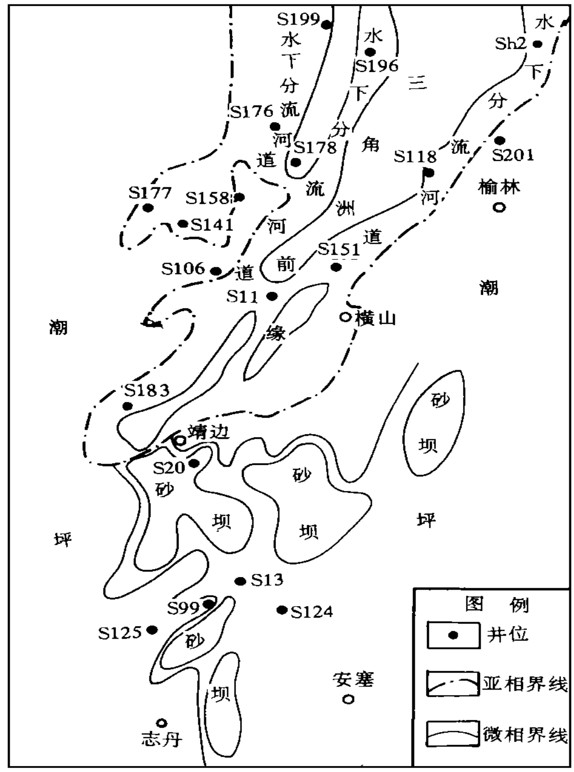

图 3　鄂尔多斯盆地中部上石炭统太原组下部沉积相平面展布图

Fig. 3　Plane distribution of sandbodies of Lower Taiyuan Fm. in Upper Carboniferous in the central part of Ordos basin

井砂体厚度 16 ~34 m。Y15—S166 井砂体厚度 20 ~40 m。

山西组上部在靖边以北发育三角洲平原,在靖边以南发育三角洲前缘。北部三角洲平原主要由分流河道微相和洪泛平原微相组成,从西到东主要发育有三条呈南北分布的砂体,分别为巴彦什力—S55 井发育带、S199—S146 井—横山发育带、E1—榆林发育带。这些砂体都具向上变细的正粒序,形态呈条带状及朵状,砂体一般宽 407 ~573 m,平均厚度 6.6 ~8.5 m。其中 E1—榆林一带的砂体是该区物性最好的储集体。岩性为岩屑质砂岩与长石质石英砂岩互层,以复合型粒间孔为特征。如 S141 井孔隙度平均为 9.10%,渗透率一般为 $5.24\times10^{-3}\mu m^2$,日产气 767 789 m^3,属储层空间良好的三角洲平原分流河道砂岩体。盆地南部的三角洲前缘相沉积主要由分流间湾、指状砂坝、水下分流河道微相组成(图 4)。其中靖边—安塞的水下分流河道砂体是

主要储气层, 具有延伸距离较长、砂体厚度薄的特征。

3.4 早二叠世下石盒子组沉积相带与砂体展布

下石盒子组沉积期, 气候由温湿演变为干热，植被大量减少, 形成一套陆相碎屑沉积。北部物源区继续抬升, 河流进一步向南推进。形成了下石盒子组北部以分流河道和洪泛平原微相组成的三角洲平原相为主、向南河流入湖处以发育鸟足状三角洲前缘为特点的沉积相特征(图 5)。砂岩分布广, 厚度一般 40～70 m。S118 井区、S148 井区砂岩厚度较大, 一般大于 80 m。整个地区有四个砂体发育带: ①桃利庙—城川和 S164—S156 井地区砂岩厚度 50～100 m, 北部厚, 向南有不明显减薄趋势, 宽度较小, 向东迅速减薄; ② E2—S178 井一带砂岩厚 70 m 左右, 向两翼递变减薄, 延伸较短; ③E4—S118 井砂体厚度 35～70 m, 宽 4～10 km, 延伸在 70 km 以上; ④靖边—志丹一带砂岩发育, 分布范围广, 延伸距离 88 km, 砂岩厚度 40～90 m。

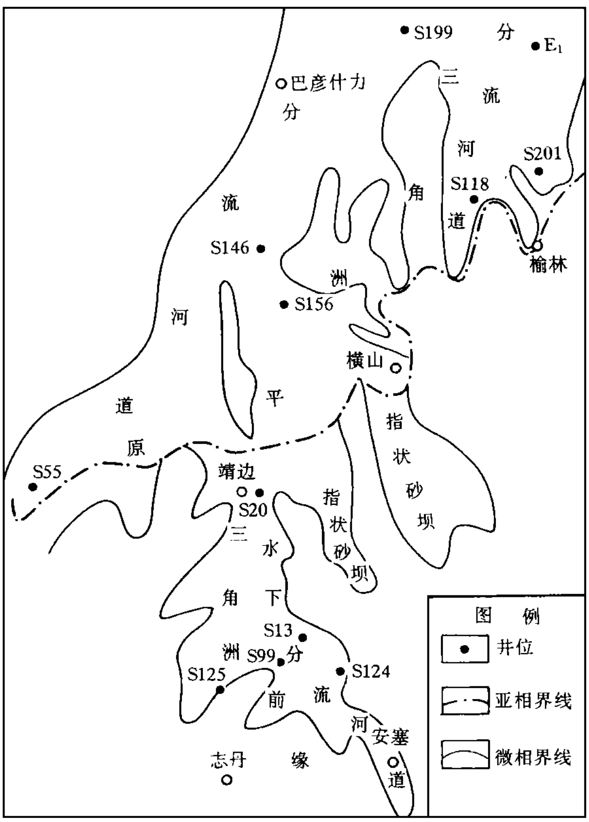

图 4 鄂尔多斯盆地中部下二叠统山西组上部沉积相平面展布图

Fig. 4 Plane distribution of sandbodies of Upper Shanxi Fm. in Lower Permian in the central part of Ordos basin

3.5 晚二叠世上石盒子组和石千峰组沉积相

晚二叠世早期上石盒子组形成大面积滨浅湖沉积, 厚 150～240 m, 岩性以杂色泥岩夹薄层粉细砂岩为主。砂泥岩比为 20%～30%。泥岩单层厚度 5～40 m, 累计厚度 80～120 m。

晚二叠世晚期, 整个鄂尔多斯地区演变成泛滥盆地沉积环境。沉积了一紫红色沙泥岩地层, 岩性混杂, 粒序不清, 成层性差, 厚 180～130 m。

4 结论

(1)本溪组和太原组上部以潮坪为主, 储层砂体薄, 分布局限。

(2)太原组中下部三角洲前缘水下分流河道砂体较为发育, 储层次生溶蚀孔隙及微裂缝最为发育, 是该区高产气井区。

(3)下石盒子组是本区砂体分布范围广, 厚度最大的层段, 其中北部三角洲平原分流河道砂体最为发育, 南部以三角洲前缘相为主, 砂体主要由水下分流河道和小型指状砂坝组成。它们构成了该区的主

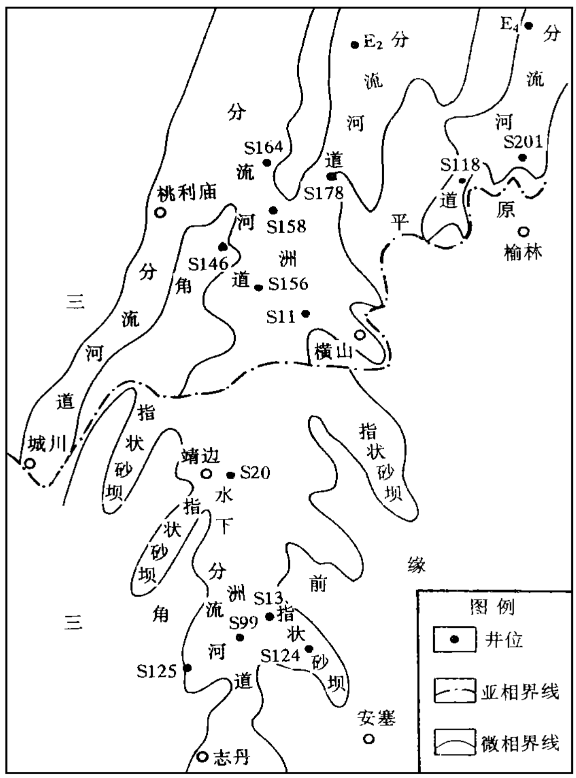

图 5 鄂尔多斯盆地中部下二叠统下石盒子组沉积相平面展布图

Fig. 5 Plane distribution of sandbodies of Lower Shihezi Fm. in Lower Permian in the central part of Ordos basin

力储集体。

(4)整个石炭—二叠纪, 以本区北部河道砂体较南部河道砂体发育为其特征。

(5)晚二叠世上石盒子组泥岩发育可作为较好的盖层。

综上所述, 鄂尔多斯盆地晚古生代石炭纪至早二叠世山西组主要为煤系沉积, 早二叠世石盒子期三角洲相发育, 晚二叠世石盒子期湖泊沉积体系广布, 构成了良好的生储盖组合。

参　考　文　献

1 杨俊杰, 裴锡古. 中国天然气地质, 卷四[M] . 北京: 石油工业出版社, 1996. 23～29
2 张福礼, 黄舜兴, 杨昌贵等. 鄂尔多斯盆地天然气地质[M] . 北京: 地质出版社, 1994. 1～33
3 李文厚, 柳益群, 冯乔等. 吐哈盆地侏罗系沉积相带与砂体展布特征[J] . 石油实验地质, 1997, 19(2): 168～172
4 刘焕杰, 张瑜瑾, 王宏伟等. 准格尔煤田含煤建造岩相古地理学研究[M] . 北京: 地质出版社, 1991. 22～50

Distribution of Sedimentary Facies Belts and Sandstone Bodies of Permo-Carboniferous in the Central Part of Ordos Basin

WEI Hong-hong[1]　PENG Hui-qun[2]　LI Jing-qun[2]
XIE Zheng-wen[2]　QI Diao-liang[2]
1 (Department of Geology　Northwest University　Xi' an　710069)
2 (Workover Company　Changqing Bureau of Petroleum Exploration　Qingyang　GanSu　745113)

Abstract

Tidal flat, delta and lake deposition of Permo-Carboniferous are well-developed in the Ordos basin with an evolution sequence changed gradually from marine to continental facies upwards. In Carboniferous, the transgression was caused by North China Sea and Qilian sea in which the former was of the largest range.

The Lower part of Benxi Fm. is tidal flat facies with very large distribution range but the Sandbody in it is relatively small. The Upper part of Benxi Fm. is the mixed deposition of turbidity and fresh water in epicontinental sea, in which formed some small bars and the delta front only distributes in the northeast of the basin. Most of elongated sandbodies from well S201 of the north to well Q1 of the south extend along NNE. Transgression range of the early period of Taiyuan Fm. in late Carboniferous is larger than that of Benxi Fm. At that time, under the influence of weak tectonic movement, subdued sea-floor, weak hydrodynamism and less sediment supply, the study area mainly developed tidal flat and delta deposits. During late period of Taiyuan Fm., the basin mainly developed tidal flat except the northeastern part of the basin where the submerged distrbutary channel of delta front prevailed . In Permian, Qinling trough began to contract again, and all north China Platform uplifted resylting in the rapid regression of sea water from east and west part of the Drdos basin. The great change of the palaeotopography and palaeoclimate led to the much wider deposition range than that of the Carboniferous. Delta plain was widespreed in the basin in the early period of Shanxi Fm. of Lower Permian. In depositional area, water became shallow and wide and the thickness of the deposits became thin. As a result of the palaeotopography, the shape of delta composed of several stacked sandbodies showed digitated, implying the obvious differential subsidence and sedimentary types between the north and south of the study area. In the north, Delta plain was well-developed, and the delta frout prevailed in the south where the submerged distributary channel from Jingbian to Ansai is the largest sandbody which is also the major reservior in the study area. In the period of Shihezi Fm., the climate changed from warm humid to dry and hot resulting in the rapid decrease of the plant, and a set of continental clastic deposits were formed. Along with the continuous rising of the prevenance area, the paleocurrent direction was always to the south. Delta plain composed of distributary channel and flood plain was formed in the north Shihezi Fm. and digitate delta front developed in the south where riversf flowed into the lake. Widespread lacustrine mudstone formed in the Upper Shihezi Fm. and Shiqianfeng Fm. of Upper Permian became the best regional caprocks in the study area.

In Permo-Carboniferou, the distributary channel sanbodies of deltaplain and submerged distributary channel sandbodies of delta front are the best reservoirs, and the tidal flat sandbody and fingered sandbody of delta front are also favorable are for exploration.

Key words the central part of Ordos basin Permo-Carboniferous sedimentary facies sandbody distribution

(**Continued from page 402**)

Fm. and Yanghugou Fm.) and tidal delta systems (Taiyan Fm.). They average about 1.9 Ma and range from 1.1 ~ 3.3 Ma in length, reflecting forth-order relative sea level change cycles, and belong to High-resolution Sequence Cycles. Each T-R sequence is composed of transgressive system tract, early highstand system tract, later highstand system tract, with a few record of forced-regression system tract. In general, lowstand ersional sequence bondary and transgressive surface are merged, with no or few record of the lowstand system tract. Transsion came from Qilian Sea during early-middle stage of Late Carboniferous. Qilian Sea and Huabei Sea were merged in Late Taiyuan stage. But they are not coincident with forth-order sea level fluctuation. It is charcterizied of forth-order sea-kevel change by the slow rising firstly and then dast rising with interenvening period of fall, and then fast falling with a few forced-regression. The third-order sea level change reflects that transgression began in Namurian C stage and reached maxium transgrssion in Wesphalian stage and occoured regression in the end of Carboniferous. So, the relative sea level change from the record of the stratigraphy sequences are the composite sea level change with small-order cycles superimposed with high-order cycles subsidence and sediment influx. Finally, sequence stratigarphic model of paleocoastal plain environment has been proposed.

Key words Orodos basin Late Carbonferous depositional system high-resolustion sequence cycle Hulusitai section