Research on Sedimentary Facies and Sedimentary System of Permo-Carboniferous Strata in Xin'an Coal Field

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Abstract. In this paper, through rock core, logging curve, plane shape, distribution and other characteristics in the research area, combined with regional data, the Permo-Carboniferous Strata in the research area experienced tidal flat sedimentary system, delta sedimentary system and river sedimentary system, flood-overlake sedimentary system from bottom to top, it is proved that basin filling evolution of the epicontinental sea basin from occurrence, development to extinction.

Keywords: Xin'an coalfield; sedimentary facies; sedimentary system.

1. Introduction
Xin'an coalfield is located in Xin'an County, Luoyang City, Henan Province; which belongs to the Late Paleozoic Era coal-bearing strata in North China, Mianchi-sagging northwestern of Queshan in Northwest Henan, and it is rich in coal resources. According to the rock core, logging curve, plane shape, distribution characteristics in the research area, combined with regional data, the sedimentary systems in the research area mainly include tidal flat sedimentary system, delta sedimentary system, river sedimentary system and flood-overlake sedimentary system.

Fig. 1 schematic diagram of traffic location of Xin'an coalfield
2. Tidal Flat Sedimentary System
The tidal flat mainly occurs in coastal areas with low wave energy and medium-to-large tidal range, for example, barrier island, lagoon, bay, tide-dominated delta, when the seabed topography are extremely gentle and the sea water is extremely shallow, the sea waves and the seabed produce strong friction, the coastal environment where energy is exhausted. The late carboniferous coal-bearing rock series in the research area is located in the epicontinental sea of North China; it is adjacent to the coastal plain of the Qinling-Dabie old land, the terrain is flat and the formation of coal-bearing rock series is mainly controlled by tidal water. Its internal genetic facies are mainly tidal channel, sand, mud mixed flat, mud flat, tidal flat swamp and peat swamp. Its internal genetic facies are mainly tidal channel, sand, mud mixed flat, mud flat, tidal flat swamp and peat swamp.

(1) Tidal channel
The lithology is generally medium and fine sandstone, bottom scour, contains mud and gravel, change from coarse to fine from bottom to top, the thickness from thick to thin, the top is argillaceous sediment, and it is often thin peat layer sediment, the bedding types have large-scale groove, bidirectional cross-bedding small-scale groove, vein type and climbing bedding.

(2) Sand and mud mixed flat
It can be seen in sequence II in the lower part of Taiyuan formation, due to the gentle topography and low-energy hydrodynamic condition, the tidal activity intensity is also weak. After retrogradation, the exposed water surface presents an exposed environment, the sediments are characterized by alternating emergence of bed material load and suspended load, and the main sediments are characterized by alternating emergence of fine siltstone and mudstone (2601 holes), there are vein bedding, lenticular bedding, gentle slope bedding and inter-bedding bedding, inter-bedding bedding and lenticular bedding are common in the research area.

(3) Mud flat
It can be seen in upper sequence III of Taiyuan formation in the research area, the sediments are mainly fine mudstone, the next is siltstone, due to the suitable climatic conditions, there are swamp facies deposits.

In a word, sequence II and sequence III in the research area show that the sediment supply rate exceeds the rise rate of sea level, forming progradational tidal flat coastal sedimentary facies sequence. The characteristics of the sequence are as follows: from bottom to top, there are sand bodies of subtidal shoals and tidal channels, low tidal flat sand bodies, middle tidal flat sand mud mixtures, and supratidal swamp deposits. The upward thinning tidal flat cycle is formed (Fig.2).

![Fig. 2 vertical sedimentary assemblage of tidal flat in the sequence II of lower part of Taiyuan formation (2601 hole, 600-630m)](image-url)
Fig. 2 is a typical example of tidal flat sedimentary assemblage, the tidal channel filling consists of genetic units with positive change, the bottom is the scour surface, groove and bidirectional cross bedding, the sand mud mixed flat is developed upward, silt and muddy sedimentary inter-bedding as the main, inter-bedding bedding, lenticular bedding and wavy bedding develop, and swamp and peat swamp facies develop above.

3. Delta Sedimentary System

The concept and classification of delta sedimentary systems are mostly originated from large river systems with enough sediment into the basin and are formed on the sedimentary surface of the marginal zone of the basin. According to the delta sedimentary characteristics and genetic facies composition identified in the research area, there are epicontinental sea shallow water delta and river-dominated lake delta two basic types.

(1) River- dominated shallow water delta and its characteristics

In the research area, the analysis and comparison of drilling and logging data, the development of shallow water delta is mainly affected by the tidal action, in this delta environment, the distributary channels of the delta plain submerge the inter-river area, and the seawater retreat when retrogradation, a tidal flat environment is formed in the area among the distributary channels, so the tidal flat is covered with tidal channels (tidal brooks, tidal canals and tidal ditches), swamps, etc., and the delta front sand bodies are also transformed into tidal sand ridges by tidal flows, there are two-way cross bedding and other tide marks inside. (Fig. 3)

The shallow water delta sedimentary system is mainly composed of upper delta plain, lower delta plain, delta front and pre delta genetic facies.

Because the research area is close to the Qinling Dabie old land and is close to the basin margin, the upper delta plain facies are mainly developed, and the branch channel sand body, crevasse shoulder, flood plain, distributary swamp and peat swamp facies can be identified.

Distributary channel facies: the distributary channel of the upper delta plain acts as a framework, and the distributary channel moves forward gradually, the distributary bay due to crevasse sedimentation and shore crossing sedimentation, the bay depression is gradually filled, the delta plain is further expanded, and a large area of swamping occurs, and finally a widespread peat swamping sedimentation is formed on the delta plain.

The sedimentation and sediment characteristics of the distributary channel are similar to those of the alluvial environment (Coleman, 1983), it is mainly composed of lateral accretion to fine sandstones, as a whole, it shows upward thinning sedimentary sequence, and the distributary channel sand body presents lenticular shape on the section, in the Shanxi formation of the study area, many stages of distributary channel sand bodies are most developed and stacked together; the bottom is usually medium grained sandstone with mud gravel, cross bedding and wavy bedding are developed. The top of distributary channel sedimentary assemblage is siltstone and mudstone sedimentation of sedimentary environment of flood plain (Fig.3).

Natural levee facies: the natural levee sediments are formed on both sides of the riverbed when the river overflows the river during flood period, and it has the sedimentary characteristics of lateral transport and vertical accretion. The natural levee is formed by lateral transport, small plate-shaped oblique bedding and climbing bedding are formed, and the grey green mudstone is formed by vertical accretion. The lithology is mainly composed of grey and greyish-green siltstone and mudstone, due to the thin sediment of the natural levee, there is a low amplitude bell shaped and finger shaped curve in the natural electric potential.

Crevasse fan facies: it is small-scale fan-shaped sediment formed during the rise period of high flood level and the natural levee is washed by strong water flow, the main lithology is mainly fine and silty, the lower part of the sedimentary sequence is a small plate-shaped cross bedding, and the upper part is a horizontal bedding, including mud gravel and plant debris, the sandstone layer is often washed, and there is also a sudden contact relationship, which is a upward thinning quasi sequence.
Flood plain facies among distributaries: it is mainly composed of siltstone and mudstone with horizontal texture, sometimes plant roots and bio drilling structure, and the natural electric potential mostly presents a straight baseline.

The swamp and peat swamp facies among distributaries: the inter-distributary swamp is developed in inter-distributary depression or inter-distributary flood plain, due to the shallow water cover, it is gradually swamped, it is mainly composed of dark gray and black sandy mudstone, mudstone, carbonaceous mudstone and coal seam with organic matter, rhizome fossils with plant, and occasionally fin and silty deposits brought in by flood period.

Fig. 3 vertical sedimentary assemblage of river-dominated shallow water delta (2601 holes, 480-540m)

(2) Lake Delta

The lake delta is a triangular sand body which is formed by sand and mud accumulation and projects to lake on the gentle slope of lake shore where rivers flow into lakes. This sand body starts from the first distributary point at the downstream of the river on the shore and enters the shore, shallow lake and deep lake area through the distributary plain of the delta on the shore, compared with the marine facies delta; because it is close to the source area, short distance transportation of weathering products of parent rock, the material composition of its sand body is much more complex than that of the marine facies delta, in the formation process of the lake delta, the river action has a great influence, the front part is transformed by the lake wave and becomes the product of the river lake interaction.

The lake delta is also characterized by three zones (layers) structure; from the shore to the center of the lake, the delta plain zone, the delta front zone and the pre delta appear successively.

Delta plain belt: it is characterized by distributary channel deposition and flood plain deposition among channels, sand and silt deposition are main, including small amount of gravel and mud gravel. It
is subdivided into distributary channel natural levee, crevasse fan, oxbow lake and abandoned river channel, etc., the plain area among distributary channels is close to the lake, there is more underground water and easy for plant growth, swamp and peat swamp facies are developed, and it is easy to form carbonaceous mudstone layer or coal seam.

Delta front zone: it is located in the coastal-shallow lake gentle slope zone below the estuary, and there are underwater distributary channel, estuary bar and sheet sand from the estuary to the lake center.

Underwater distributary channel: it is an extension of distributary channel facies in the lake on the delta plain, the stronger the river is, and the farther the river is extended, it is distributed in a strip vertical coastline, the lithologic profile is superimposed sandstone formed by multilayer positive rhythm sand superimposition, the logging curve is box and bell shape.

Estuary dam: it is the most characteristic sand body in the delta, it appears in the estuary where the distributary channel flows into the lake, on the transverse section (vertical flow direction), and it presents an asymmetric lens body, there are many materials at one end of the estuary, which is the whole of the dam sand. Because of the winnow of lake, the estuary dam forms a thick layered massive sand layer with inverse grain sequence.

Front Delta: in front of the estuary dam, there are widely distributed sheet sand dams and muddy deposits with thin thickness and fine grain size, namely the front of the delta front is usually dark mudstone or sheet sand body.

In the formation process of the sand body of the lake delta, due to the hydrodynamic action of the river and the lake, the sand body of the sand dam at the estuary continuously advances to the center of the lake, which successively covers the tail end of the sand dam, the sheet sand dam and the mudstone of the front delta, therefore, there is an upward thickening anti-rhyming sequence on the vertical section (Fig. 4).

**Fig. 4** vertical sedimentary assemblage of Lake Delta (2601 holes, 360-420m)

4. Sedimentary System of Rivers
In the late stage of Permo-Carboniferous sedimentation, the Shangshihezi formation and Shiqianfeng formation, fluvial depositional system is widely developed in the research area. The research area is adjacent to the Qinling-Dabie old land, its large slope and braided river deposition. It can be divided into distributary channel bottom sedimentary facies, channel sand dam facies and flood plain facies (Fig.5).
Sedimentary facies at the bottom of the distributary channel: retained gravel is developed at the bottom of the channel, which is covered on the underlying scour surface, the sand layer above bottom load with transported form, and large-scale groove and plate cross bedding is developed.

Channel sand dam sedimentary facies: it is the sand body and the core beach separating the river channel, it is exposed on the water surface when the water level is low, and the water inflow and high water level are submerged by the flood, it is mainly composed of medium fine sandstone, there are small groove bedding and cross bedding developed.

Flood plain sedimentary facies: the flood plain sediments are mainly silt and clay deposited by flood, the horizontal texture can develop peat layer.

5. Flood-overlake Deposit
Flood-overlake deposit is a special type of lake which is different from general river facies, shore and shallow lake facies, as well as general delta facies, instead, it flows from flood to flat shallow lake, which is related to the injection of near source paroxysmal flood and the subsequent sedimentation. In the research of the lower fourth section of Kongdian Formation in Dongpu depression Zhao Chenglin (1992) think that the red bed of Kongdian formation is flood-overlake deposit, and pointed out that flood-overlake deposit is a set of light colored sandstone and siltstone similar to Bauma sequence deposited under high energy condition. In the open and flat lakeshore environment, in the high water level period of flood, flood flows into the basin, and the scour and filling of flood water flow form the deposition of flood channel, while the fine debris transported by flood scour overflows out of the channel and flows into the basin, and overflows everywhere to form the overflowing deposition. From the watercourse to the distance, the sedimentary materials gradually become thinner and cover on other sedimentary materials, and multi-stage flood events form vertical sedimentary sequence overlapped by flood waterway deposits and over-lake deposits (Fig. 6).
In the study area, the flood-overlake deposit is mainly developed in the transgressive system tract of sequence 6 and 7 of the upper Shihezi formation, the lake basin has a flat terrain, arid or semi-arid climate, and there are paroxysmal floods flowing into the lake, form fan sand body similar to the supply channel (Wu Chongyun, 1988). V

Channel sedimentation: the channel sedimentation is the restricted water flow sedimentation formed after seasonal flood flowed into the lake, which is mainly composed of clastic sandstone facies, bottom scour structure, including argillaceous inclusion and rock gravel, show progressive bedding, upward grain size thinning, small groove cross bedding, and well logging curve is box or bell shape.

Overlake sedimentation: it is formed by the restricted flow of flood turning into the non-restricted flow and then overflowing around, it is usually silty sand and argillaceous deposit, sometimes it can form sheet sand body, generally the sandy deposit deposited by flood overflowing and the normal lake deposit intermittently by flood form an overlapping vertical sequence (the logging curve is zigzag accretion) (Fig. 6, Fig. 7, Fig.8).
6. Conclusion
The Permo-Carboniferous strata in the research area have experienced tidal flat sedimentary system, delta sedimentary system, river sedimentary system, flood-overlake sedimentary system from bottom to top, it proves that the epicontinental sea basin in the research area evolves from occurrence, development to extinction of the basin filling, and forms Permo-Carboniferous coal-bearing rock series in the total process of sea area expansion to gradual retreat, the formation of coal-bearing rock series is closely related to the advance and retreat of sea water caused by the rise and fall of base level, coal seams are mostly formed in coastal plain and delta environment, with the advance and retreat of sea water, the coal accumulating process moves synchronously and the base level changes, it not only forms obvious cyclic strata, but also makes the coal accumulating process show obvious stages.
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