The Relationship between the Distribution of Thick Coal Belts and the Late Carboniferous–Early Early Permian Marine Transgression–Regression in the North China Platform

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Abstract Four great second–order transgressions occurred during the Late Carboniferous to early Early Permian and they came from both the eastern and western sea areas in the North China Platform. As time went on, depocentres, depositional extent, transgression directions, coastline position and distribution of minable coal seams were changing continuously. The third great second–order transgression occurring at the beginning of the early Early Permian marks the maximum transgression period and before its arrival, i.e. at the close of the late Late Carboniferous, there was the super–regional coal–forming environment. During the second, third and fourth transgressions, the northern North China Platform was all along situated on the transgressive margin of the epicontinental sea and became the major distribution area of thick coal belts because it maintained a coal–forming environment for a long period of time from the close of the late Late Carboniferous to the Early Permian.

Key words: Late Carboniferous–early Early Permian, marine transgression–regression, thick coal belt, North China Platform

The study extent involves the Benxi and Taiyuan Formations in the North China Platform. The authors have carried out detailed field and lab studies for dozens of surface geological sections and cores from hundreds of boreholes (Fig. 1) and, based on the new stratigraphic correlation scheme and the analysis of sedimentary environment, defined the distribution of sedimentary facies, directions of both terrigenous clast supply and transgressions, and the relationship between the distribution of thick coal belts and marine transgression and regression.

Study of the relationship between the distribution of thick coal belts and the marine transgression–regression requires a correct stratigraphic correlation scheme. On the basis of previous biostratigraphic study, the authors made a stratigraphic correlation of the Benxi and Taiyuan Formation of the Late Carboniferous–early Early Permian in the North China Platform, taking the volcanic event layers widespread over several provinces as the marker bed for super–regional isochronous stratigraphical correlation (Zhong et al., 1996a)

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in conjunction with the largest marine transgression event layer. A new scheme was then put forward by the authors (Chen and Zhong, 1993; Peng and Zhong, 1995; Zhong et al., 1995, 1996b, 1996c).

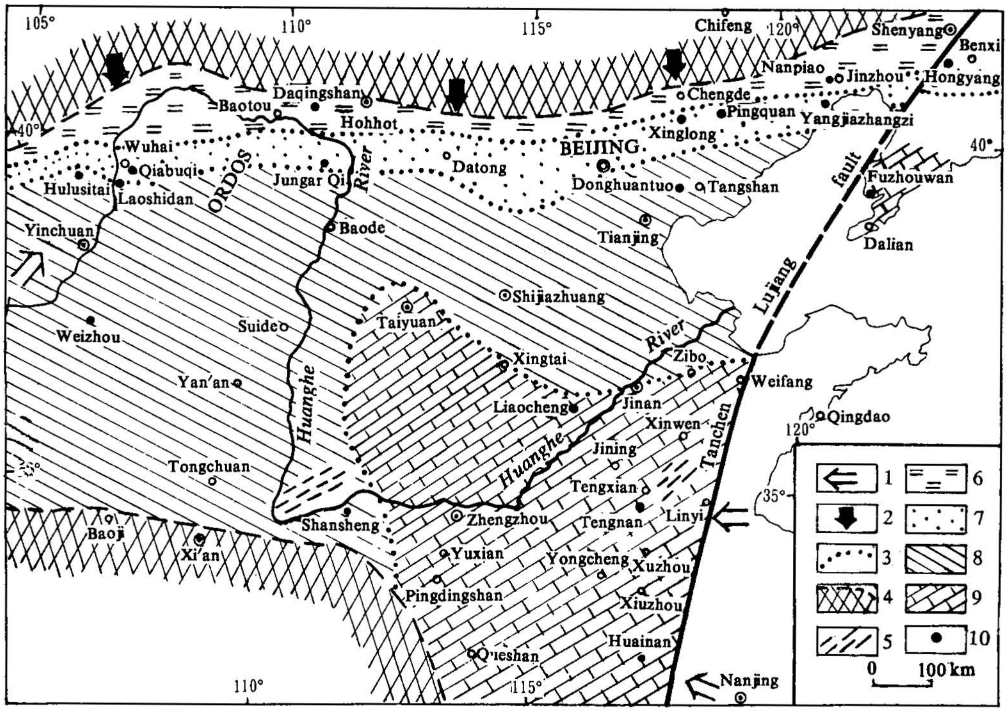
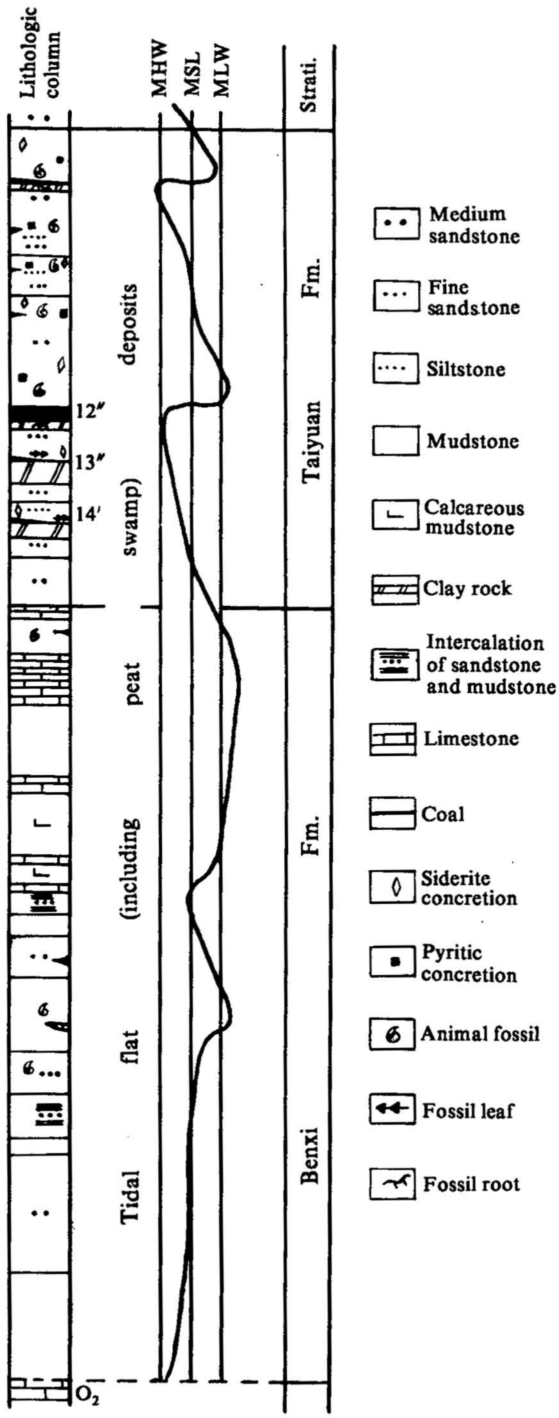


Fig. 1. The sedimentary environments and sea–level changes of the Benxi and Taiyuan Fomations in the Benxi coalfield of the North China Platform.

MHW–mean high–water level; MSL–mean sea level; MLW–mean low–water level.

Discussion of marine transgression and regression should be based on the study of sedimentary environment, which exercises influence on coal accumulation and occurrence and hence becomes one of the important factors controlling the distribution of coal resources. The analysis of sedimentary environment is essential for correct understanding of the relationship between thick coal belts and marine transgression–regression.

The Benxi and Taiyuan Formations were in the North China Platform formed mainly in a fairly gentle and shallow epicontinental sea sedimentary basin on the continental shelf. In the epicontinental sea are distributed mainly carbonate platform depositional areas and tidal flat depositional areas covering tens of square kilometers, often associated with various tempestites. Some underwater uplift areas existed in the epicontinental sea sedimentary basin in the North China Platform (Fig. 2) and they would be exposed when the sea water fell to become local sources of terrigenous clasts. It is noticed also that in this period, instead of fluvial and alluvial fan deposits, there formed shallow–water deltaic deposits and near–mountain littoral plain deposits near the old land side of the northern part of the epicontinental sea basin of the North China Platform (Zhong, 1984, 1989). A brief discussion of sedimentary environment will be given in the following.



(1) Epicontinental sea carbonate platform deposition The depositional boundary lies between the low–water level and the wave base with the water being several meters and dozens of meters in depth (not deeper than 30 m in general) and predominated by subtidal deposits. The carbonate platform deposits, mainly limestones, appear many times in the Benxi and Taiyuan Formations. They can be divided into open platform and restricted platform deposits.

(2) Tidal–flat deposition Tidal–flat deposits are extensively distributed in the Benxi and Taiyuan Formations. They belong to carbonate tidal–flat deposits, terrigenous clastic tidal–flat deposits and mixing tidal flat deposits of carbonate and terrigenous clast. (a) The carbonate tidal–flat deposits, predominated by intertidal–flat deposits, can be further divided into such deposits as upper–intertidal flat including peat flat (Liu et al., 1992), middle intertidal flat, lower intertidal flat, tidal creek with occasional supratidal flat deposits. (b) The terrigenous clastic tidal–flat deposits can be subdivided into supratidal flat (including swamp, peat swamp and peat flat etc.), intertidal flat, subtidal flat (including subtidal lagoon), tidal creek, tidal channel and barrier beach

Fig. 2. The sketch map of sedimentary facies and palaeogeography during the maximum transgressive period of Carboniferous in the North China Platform.

1—Transgressive direction; 2—terrigenous supply direction; 3—sedimentary facies boundary; 4—old land; 5—under water uplift area; 6—near–mountain littoral plain sedimentary facies; 7—terrigenous clast tidal–flat sedimentary facies; 8—carbonate tidal–flat sedimentary facies; 9—epicontinental carbonate platform sedimentary facies; 10—coalfield or coal mine.

(or tidal beach) et al. The intertidal flat deposits can be divided into upper–intertidal flat (including peat flat), middle intertidal flat and lower intertidal flat. (c) The mixing tidal flat deposits of carbonate and terrigenous clast are spatially distributed between the terrigenous clastic tidal–flat depositional area and the carbonate tidal–flat depositional area with intertidal flat deposits most commonly seen, which are represented by such rocks as marl and sandy limestone.

(3) Shallow–water delta deposition It is observed only in the Taiyuan Formation. The shallow–water delta deposition, belonging to river–dominated delta deposition, is influenced by tidal action in varying degrees and a transition often exists between this deposition and the terrigenous clast tidal–flat deposition. Delta plain deposits are mostly developed with minor delta–front deposits in shallow–water delta deposition with prodelta deposits being hardly seen. Delta plain deposits can be divided into such deposits as swamp, peat swamp, distributary channel and interdistributory bay etc. (Zhong, 1985).

(4) Near–mountain littoral plain deposition Crustal uplifting in the provenance often caused extensive development of rivers and alluvial fans. After the water of the river and alluvial fan carrying clasts flew into littoral regions, littoral sand or gravel banks namely foreshore and backshore deposits, were produced due to reworking by littoral water flows. The deposits of the near source part of rivers and alluvial fans could not be kept in their initial positions but were retransported due to repetitious uplifting of the provenience. What we can see today are mainly near–mountain littoral plain deposits. It is necessary to mention that the broad backshore depositional region is generally favourable for the development of peat swamps during the period featuring gentle topography in the provenience and humid hot palaeoclimate. In other words, near–mountain littoral plain deposits mainly include foreshore deposits and backshore (including peat swamp, swamp and small channel etc.) deposits. Analysis of coal facies indicates that peat swamp deposits can be further divided (Zhong, 1987).

It can be seen from the above discussion that the most favourable sedimentary environments for coal accumulation are all situated in littoral regions of the epicontinental sea, including the depositional areas of backshore peat swamp, delta plain peat swamp, terrigenous clast supratidal peat flats (Liu et al., 1992) and terrigenous clast supratidal peat swamp.

The formation of thick coal belts is controlled by an optimal combination of palaeoclimate, palaeogeography and palaeotectonics. The North China Platform was situated in a humid hot palaeoclimate zone during the Late Carboniferous to Early Permian, which is very favourable for coal formation. The tectonic setting of this area was relatively stable at that time and very suitable for the formation of thick coal seams. Searching for the most favourable sedimentary environment for coal accumulation is the key to search for thick coal belts in these favourable palaeoclimatic and palaeotectonic conditions. Littoral regions of the epicontinental sea, whose distribution was controlled by marine transgression–regression, present the most favourable sedimentary environment for coal accumulation.

The Benxi and Taiyuan Formations in the North China Platform is a coal–bearing measure consisting of repeatedly alternating carbonate rocks, terrigenous clastic rocks, pyroclastic rocks and coal seams, indicating a high frequency of epicontinental sea–level changes during the deposition of these formations. The change of sea level is related to the global elevation and subsidence of sea level, tectonization, compensation of deposits, changes in palaeotopography and palaeoclimate, storm and tides et al. The elvation and subsidence of global sea level control the first–order marine transgression and regression, which occurred only once throughout the late Palaeozoic in the North China Platform. The second–order marine transgression–regression is largely related to super–regional tectoniczation and the palaeotopography of the basin. Studies show that the second–order marine transgression and regression had occurred four times during the Late Carboniferous–early Early Permian period in the North China Platform. The third–order transgression and regression were related to local tectonization (e.g. local subsidence of the basement caused by synsedimentary faulting and structural uplifting of the provenience), compensations of deposits (including inner source, terrigenous and volcanic source), changes in palaeotopography and palaeoclimate, storms and tides et al. The third–order marine transgression and regression took place at least twenty–one times during the late Carboniferous–early Early Permian. In some areas combinations of several events of third–order marine transgression and regression might have occurred owing to complex influence and interference. Therefore, numbers of marine transgressions recognized on the stratigraphic profiles vary greatly from area to area in the North China Platform. This paper mainly discusses the relationship between the distribution of thick coal belts and the second–order transgression and regression.

During the first great second–order transgression occurring at the beginning of the early Early Carboniferous only a few areas on the eastern and western margins of the North China Platform received deposits. The Pacific advanced westwards toward the Fuzhou Bay, Liaoning, and the Linyi, Shandong, et al. on the eastern margin of the North China Platform, i.e. these areas of depocentres, where mainly epicontinental sea carbonate platform deposits were formed, while tidal–flat deposits were mainly formed in its surrounding areas including Benxi, Liaoning, and Tangshan, Hebei. The Qilian Sea invaded the western margin of the North China Platform from the southwest, bringing about mainly subtidal lagoon and tidal–flat deposition.

In the later part of the early Late Carboniferous, when the second great second–order transgression occurred, most part of the North China Platform subsided to receive deposits except the northern margin and southern part of the North China Platform and the central part of the Ordos area of the North China Platform. The sea water of the Pacific to the east of the platform was still transgressing from east to west on a much greater scale the epicontinental sea was, causing inundation of the northern and central parts of the eastern North China Platform, and the depocentres shifted to Benxi, Liaoning① and the Zibo–Xinwen area, Shandong. In these areas mainly carbonate platform–tidal flat deposits were formed, while tidal–flat deposits were mainly formed in most other areas (except the northernmost area). Sand or gravel beaches of near–mountain littoral plain, namely foreshore and backshore deposits, are characteristic deposition of the Daqingshan and Nanpiao et al. coalfields in the northernmost part of the eastern North China Platform (Zhong, 1987). The Qilian Sea invaded the western of the North China Platform still from the southwest with a slightly larger extent. In the depositional area which had been forming

① The Benxi coalfiled of Liaoning Province features a complete development of the four great second–order marine transgression–regression events.

since the beginning of the early Late Carboniferous subtidal lagoon and tidal–flat deposits kept developing and foreshore and backshore deposits, just a few metres in thickness, are received in its surrounding areas.

In the late Late Carboniferous there was a remarkable reduction of sea water' s invasion from the Pacific side and the epicontinental sea carbonate platform deposits were replaced by tidal–flat deposits in the basin; the transgression from the Qilian Sea was also weakened with subtidal lagoon deposits being replaced by intertidal–flat and supratidal–flat deposits. At the close of the late Late Carboniferous, the northern and central parts and western margin of the North China Platform became swamped, and stable minable coal seams along with local medium–thick coal seams were developed because of ever lower and gentler topography of the provenience on the northern margin of the North China Platform, gradual peneplanation of the palaeotopography of the depositional basin and humid hot palaeoclimatic condition.

At the beginning of the early Early Permian the third grat second–order transgression occurred (Fig. 2) and the southern North China Platform and the central part of the Ordos area had subsided and received deposits. On the east side of the North China Platform, the transgression of the Pacific came from ESE, but in the Qilian Sea it was still coming from the southeast. The eastern and western sea areas became connected and the maximum transgression appeared. During this period, epicontinental sea carbonate platform deposits and tidal–flat deposits covered almost the whole North China Platform except its northern part, where the near–mountain littoral plain deposits were still formed (backshore peat swamp deposits existed in many places in this area where there remained a favourable coal–forming environment).

The early Early Permian still had humid hot palaeoclimate, hence favourable for coal formation. Owing to repeated, intermittent uplifting on the northern margin of the North China Platform, there was an attenuation of sea invasion and gradual southward shifting of the coastline and the coal–forming environment extended also towards the south. Subsequently, a number of minable coal seams were developed in the central part of the North China Platform, while coal–forming environment still remained in some areas of the northern North China Platform.

At the end of the Early Permian there occurred the fourth great second–order transgression with a remarkable intensive sea invasion. As compared with the third one, it was smaller in extent, but had the same direction.

The northern North China Platform had been all alone situated on the margin of the transgression of the epicontinental sea throughout the second, third and fourth great second–order transgressions. From the late Late Carboniferous to early Early Permian, the coal–forming environment (backshore peat swamp and delta plain peat swamp) had remained for a long period because of favourable palaeoclimatical conditions and stable subsidence rate of the crust, so this region became the major distribution area of thick coal belts.

In a word, the end of the late Late Carboniferous, which was immediately followed by the maximum marine transgression, is the best period providing a super–regional coal–forming environment. During the period of numerous great transgressions, the region was all along the transgressive margin of the epicontinental sea, namely the northern part of the North China Platform, which is the major area for the formation of thick coal belts.

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References

Chen Fen, Zhong Rong, Wang Jingdong and Deng Shenghui, 1993. Stratigraphic attribution of the large thick coal seam in Xinglong coal field, Hebei Province. *Geosciences*, 7(1): 1–8 (in Chinese with English abstract).

Liu Huanjie, Jia Yuru, Long Yaozhen, He Kanglin, Ma Hongying, Guo Yinghai, Shi Jian and San Shuxun, 1992. Progress in Coal–forming Theory of Marine Facies. *Acta Sedimentologica Sinica*. 10(3): 47–56 (in Chinese with English abstract).

Peng Gelin and Zhong Rong, 1995. Discovery of volcanic event deposits and stratigraphic correlation of Taiyuan Formation in western margin of North China. *Geosciences*, 9(1): 108–118 (in Chinese with English abstract).

Zhong Rong, 1985. A deltaic sedimentary model in coal–bearing formation. Papers dedicated to the 27th International Geological Congress. 121–129 (in Chinese with English abstract).

Zhong Rong, 1989. On study of sedimentary environment of Carboniferous coal–bearing formation in Daqingshan coalfield, Nei–Mongol. XI^{e} Congrès International de stratigraphie et de Géologie du Carbonifère Beijing, 1987, No. 5. Compte Rendu. 87–95.

Zhong Rong, Sun Shanping, Chen Fen and Fu Zeming, 1995. The discovery of rhyo–tuffite in the Taiyuan Formation and stratigraphic correlation of the Daqingshan and Datong coalfields. *Acta Geoscientia Sinica*, Bulletin of CAGS, 16(3): 291–301 (in Chinese with English abstract).

Zhong Rong, Sun Shanping and Fu Zeming, 1996a. The characteristics of volcanic event deposits and their regularity at the temporal–spatial distribution of Benxi and Taiyuan Formation in the North China Platform (NCP). Dedicated to the 30th International Geological Congress, Special Issue of Acta Geological Sinica, Bulletin of the CAGS, 119–124.

Zhong Rong, Chen Fen, Fu Zeming and Yuan Ding, 1996b. Progress on Carboniferous stratigraphy and sedimentology in western Liaoning Province. *Geosciences*, 10(3): 293–302 (in Chinese with English abstract).

Zhong Rong, Sun Shanping and Fu Zeming, 1996c. Late Carboniferous–Early Permian volcanic event deposits and stratigraphic correlation in Shandong Province and its adjacent regions. *Acta Geological Sinica* (English edition), 9(4): 380–394.

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