Mesozoic basins and associated palaeogeographic evolution in North China

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Abstract In North China, the Mesozoic terrestrial basins, sedimentary palaeogeography and tectonic settings involved five evolutionary stages: (1) the Early–Middle Triassic, (2) the Late Triassic to Early–Middle Jurassic, (3) the Late Jurassic to early Early Cretaceous, (4) the middle–late Early Cretaceous and (5) the Late Cretaceous. The regional punctuated tectonic events occurred during these evolutionary stages.

During the Early–Middle Triassic (stage 1), the Xingmeng Orogenic Belt (XMOB, i.e., eastern part of Central Asia Orogenic Belt, CAOB) of the northern North China was settled in the transition of tectonic environment from syn-orogenic compression to post-orogenic extension with intensive uplifting. It is a main provenance in the unified Ordos–North China Basin. The united continental plate of China and the Qinling–Dabie–Sulu Orogenic Belt formed due to convergence and collision between the North China Plate and the Yangtze Plate along two suture zones of the Mianlue and the Shangdan in the terminal Middle Triassic.

During the Late Triassic to the Early–Middle Jurassic (stage 2), the Late Triassic mafic or alkaline rocks and intrusions occurred on the northern and southern margins of North China Craton (NCC) and XMOB, implying that intensified extension happened all over the North China (early phase of stage 2). Additionally, in the late phase of stage 2, the basic volcanic-filling faulted basins were widely distributed in the northeastern North China during the Early–Middle Jurassic, including a series of small- to medium-sized basins with coal-bearing strata and some volcanic rocks in other areas of North China, which was the result of subduction of the Palaeo-Pacific Plate during the Early–Middle Jurassic. An active continental margin with accretionary complex developed in the eastern Heilongjiang of China, Japan and the Far East of Russia at that time. However, in the end of the Early–Middle Jurassic, because of the Yanshanian orogeny characterized by complicated thrust and fold, the previous unified Ordos–North China Basin was separated by the northeast-oriented Great Xing’an Range and Taihang Mountain uplifted lineament. The differential evolution of basins and sedimentary palaeogeography between eastern and western North China was initiated, and was interpreted to result in the closure of Okhotsk Ocean and the subduction of Palaeo-Pacific Plate (late stage 2).

During the Late Jurassic (the early phase of stage 3), a variety of faulted basins occurred in the Yanshan and Yinshan areas in the northeastern North China. In Yanshan area, basins were filled with thickened intermediate volcanic rocks and purple-red coarse-grained clastic rocks. In contrast, only thick layered sedimentary rocks with rare volcanic rocks developed in the Yinshan faulted basins, the Ordos Basin and basins in southern North China. XMOB was

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the main provenance of the Early Mesozoic basins in the North China, while the Ordos Basin and the Hefei Basin were partly supplied by the northern Qinling Orogenic Belt.

During the Late Jurassic–early Early Cretaceous (the late phase of stage 3), the northern and northeastern North China experienced extensional movement after the subduction of the Palaeo-Pacific Plate, the closure of the Mongolia–Okhotsk Ocean and the subsequent Yanshanian orogeny. At the same time, a NE-oriented, giant rift basin system (NE Asia Rift) extended from the Yanshan to the western Great Xing’an Range, where rift basins were filled with the regional, NE-oriented, thick coarse-grained clastic rocks and a belt of volcanic rocks. In the meantime, the eastern and northeastern China and most areas of NCC were presented as highland terrains.

During the middle–late Early Cretaceous (stage 4), rift basins developed and accumulated alluvial sediments and interbedded alkaline volcanic rocks in the western and northern North China, including Yingen, Ejinaqi and Erlian regions. Basins were formed on both sides of the Tan-Lu Fault Zone under a striking-slipping force. Furthermore, faulted basins developed in the Yishu Fault Zone of Shandong (central Tan-Lu Fault Zone) as well, where dinosaur fauna flourished. Basic volcanic rocks and fluvial–lacustrine sediments were deposited in small- or medium-sized rift basins in the northeastern China. The Songliao Basin was a typical giant basin that was mainly filled with late Early Cretaceous lacustrine sediments. A group of rift basins occurred in the Sanjiang area, central Heilongjiang Province, northeastern China.

From the middle–late Early Cretaceous to the Late Cretaceous (stage 5), depositional and subsiding center of the basins constantly shifted southeastwards in Heilongjiang Province. The tectonic setting changed into the Palaeo-Pacific continental margin in north and northeastern China.

Besides, during the Late Mesozoic, a huge terrestrial biota, mainly dinosaur fauna, dominated in North China. The Yanliao biota of the Middle–Late Jurassic and the Jehol biota of the Early Cretaceous are characterized by feathered dinosaurs, primitive birds, mammals, pterosaur, insects and plants (angiosperms). In northeastern Asia, this Late Mesozoic tectonic background, palaeogeography and palaeoecology were shared by East China, Korean Peninsula, Japan and the Far East of Russia.

Key words Mesozoic, basin, orogenic belt, tectonic zone, palaeogeography, North China

1 Introduction

The Mesozoic is an important period in the evolutionary history of the Earth which was partially covered by the broad Tethys Ocean (the Tethys domain) and widely distributed terrestrial basins. Since the Late Mesozoic, a number of important geological events had taken place in the Tethys domain, such as Pangea break-up (Keppie et al., 2004; Veevers, 2004), Tethys closure (Sone and Metcalfe, 2008), the formation of Mongolia–Okhotsk tectonic zone in Central Asia Orogenic Belt (Metelkin et al., 2007; Pei et al., 2011; Donskaya et al., 2013) and the Pacific Ocean expansion (Kemkin, 2008; Chough and Sohn, 2010; Zhang et al., 2012a). Simultaneously, in terrestrial environments, a series of important geological/tectonic events with global-scale implications occurred successively, for example, the extension of Circum Pacific Orogenic Belt from North and South America to the northeastern Asia, subduction of the Palaeo-Pacific Plate, the closure of the Mongolia–Okhotsk Ocean and its subsequent orogeny, the occurrence of Yanshanian Orogeny in the intra-plate of North China (Davis et al., 2001; Yang et al., 2006), large-scale volcanic activities and mineralizations in eastern China (Xu et al., 2013) and the destruction of the North China Craton (NCC) (Zhai et al., 2007; Li et al., 2012a; Zhang et al., 2012b; Zhu et al., 2012a, 2012b; Tang et al., 2013).

Then, extensive volcanic–magmatic–orogenic activities in the Mesozoic terrestrial environments of North China resulted in the complex and diverse palaeogeography, along with a rapid evolution of flourishing flora and fauna. For example, dinosaur fauna was a dominant creature which lived through the fast radiation during the Late Mesozoic
and the mass extinction during the Late Cretaceous (Zhou et al., 2003). Therefore, the Late Mesozoic of North China had important implications on terrestrial palaeogeography, palaeoclimatology and palaeoenvironment, as well as the complicated global tectonic background, which has been a research focus for long-term.

In recent years, the authors, supported by the National Science Foundation of China and China Geological Survey, carried out systematic investigations and comprehensive studies of sedimentary–tectonic evolution and associated palaeogeography, focusing on the Mesozoic sedimentary basins in North China. Based on the tectonic evolution stages of the Mesozoic basins, this paper analyzed and summarized not only the spatial-temporal evolution of the Mesozoic terrestrial palaeogeography and palaeoenvironment, but also the tectonic activities in North China.

2 Geological setting

North China includes the Tianshan–Xingmeng Orogenic Belt to the north, the North China Craton (NCC) to the south and the East Asian continental margin (Figures 1, 2). The Tianshan–Xingmeng Orogenic Belt, which experienced a long-term accretive arc–continent collision with a similar orogenic history as the Tethyan tectonic domain, was the world’s largest Paleozoic accretive orogenic belt, and formed at about 250 Ma along the Solonker suture (Xiao, 2004, 2009, 2013; Li et al., 2006). The Mongolia–Okhotsk Ocean closed during the Jurassic–Cretaceous (Donskaya et al., 2013; Zhou and Wilde, 2013) (Figure 1).

The NCC, as one of the world’s oldest cratons, was finally cratonized in ca. 1.85 Ga, and then experienced extension during the Late Paleoproterozoic, stabilizing as a platform during the Middle Neoproterozoic (Zhai et al., 2000; Zheng et al., 2013), receiving marine sediments during the Paleozoic, having depositional hiatus from the Middle Ordovician to the Carboniferous, and accumulating terrestrial deposits since the Permian. The Tan-Lu Fault Zone crosses the eastern part of NCC and the Jilin–Heilongjiang Provinces (Figure 1).

The southeastern region of NCC hosted the Qinling–Dabie–Sulu Orogenic Belts which were formed by collisions of South China Block and North China Craton during the Early Mesozoic and were symbolized the Paleozoic–Mesozoic continental collision and ultra high pressure (UHP) metamorphism (Zhang et al., 2004; Zheng et al., 2013). The southwestern region of NCC contained the Qilian Orogenic Belt that recorded the closure of Tethys Ocean (Zhang et al., 2004). The eastern region of NCC belonged to the continental margin of East Asia, which not only was the eastern edge of the Palaeo-Pacific Plate since the Mesozoic, but also constituted the complex tectonic setting of the Palaeo-Asia and northwestern Pacific Ocean since the Paleozoic (Li, 2006; Zheng et al., 2013). The eastern part of present Heilongjiang was located in the active continental margin of the Palaeo-Pacific subduction zone during the Late Jurassic (Kojima, 1989; Kirillova, 2003; Kemkin, 2008).

3 Mesozoic basin evolution, palaeogeography, and tectonics in North China

Mesozoic basins were widely distributed in North China (Figures 2, 3). On the basis of sedimentary palaeogeography and tectonic settings, five evolutionary stages can be identified in chronological order, i.e., (1) Early–Middle Triassic, (2) Late Triassic to Early–Middle Jurassic, (3) Late Jurassic to early Early Cretaceous, (4) middle–late Early Cretaceous and (5) Late Cretaceous. Between each individual evolutionary stage, there were regional punctuated tectonic deformation (event) surfaces (Figure 3).

3.1 Stage 1: Early–Middle Triassic

During stage 1 (Figure 4), the North China was char-
acterized by differentiated palaeogeographic and tectonic evolution from south to north. The Junggar–Turpan–Hami area was a unified basin located in northwestern China in the Early Triassic, which was under the distance effecttion of the Tethys evolution in Qinghai–Tibet Plateau and the northward compression. The uplifted mountains around the basin are provenance and result in the purple-red fluvial-lacustrine sediments of the Early Triassic.

North China was in a syn-orogenic or post-orogenic tectonic setting, e.g., the Tianshan–Xingmeng accretionary orogeny or Central Asian Orogeny through the Late Palaeozoic to Early Triassic. The northern margin of NCC and the Xingmeng Orogenic Belt were strongly compressed which demonstrated the syn-orogenic and uplift tectonic features. The Ordos–North China was represented by a giant basin with widely-distributed facies assemblages of alluvial fan–fluvial and shallow lake facies. In Yanshan region, the Lower–Middle Triassic was dominated by alluvial fan and fluvial channel deposits of purple-red sandstone and mud sediments, which were deposited in western Shandong as well. In southern North China and northern Qinling Mountain, however, the Lower–Middle Triassic was dominated by alluvial fan–fluvial and shallow–deep lacustrine facies assemblages. During the Early–Middle Triassic, the North China Plate and the Yangtze Plate approached together and by the end of the Middle Triassic, collision between the North China Plate and the Yangtze Plate occurred along the Qinling–Dabie–Sulu subduction belt, which caused uplift and extensive erosion in the southeastern region of North China and palaeogeographic rising of the southeastern North China. At that time, palaeogeographic highlands were widely distributed in eastern and northeastern China, and in Xingmeng Orogenic Belt (XMOB). Hence, most areas of XMOB and northeastern China were represented by the palaeogeographic highlands, which consisted of the main provenance of Ordos–North China Basin (Li et al., 2013a, 2013b; Yang et al., 2013). Palaeo-currents and provenances including detrital zircon analysis of the Lower–Middle Triassic sediments indicated a bidirectional sedimentary supply pattern from either northern Qinling Mountain or XMOB and northern North China to the central Ordos–North China Basin (Figure 4).

3.2 Stage 2: Late Triassic to Early–Middle Jurassic

The stage 2 (Figures 5, 6) is characterized by most intense regional extension in North China in the previous uplift terrains. In the northern area of the northeastern and eastern China, highlands collapsed successively. In the
sediments depositional facies zones consisting of coarse and coal-bearing fluvial sediments. Besides, the ringlike intermediate lavas at bottom overlaid by lacustrine however, the dominant deposits of the eastern areas were basic–intermediate rocks and coal-beds developed well in North China and northeastern China. Across the Junggar–Turpan-Hami Basin in northwestern China, and in the western areas of the gravity gradient zone from the Great Xing'an Range to the Taihang Mountain, there deposited thick coal-bearing lacustrine and fluvial sediments, however, the dominant deposits of the eastern areas were basic–intermediate lavas at bottom overlaid by lacustrine and coal-bearing fluvial sediments. Besides, the ringlike depositional facies zones consisting of coarse-grained sediments of fluvial fans and channels surrounded in the Hexi Corridor Basin and the Ordos–North China Basin, and the palaeocurrents towards the central Ordos–North China Basin, suggested that their sediment provenances were the uplift mountains around these basins. But, palaeocurrent and provenance analysis of the Jurassic deposits in West Shandong Province showed that these sediments came from East Shandong to the East Tan-Lu Fault Zone and northern North China or Central Asia Orogenic Belt (Yang et al., 2013).

Furthermore, during the late Early–Middle Jurassic, the Yanshanian orogeny characterized by complicated thrusts and folds was widely developed in North China (Davis et al., 2001; Cope et al., 2007), which led to a differential basin evolution in western and eastern regions of North China. Thus, the previously unified Ordos–North China Basin was split into two sub-basins (the Ordos Basin and the North China Basin) due to synchronous uplift along the NE-oriented line from the Great Xing’an Range to Taihang Mountain (the gravity gradient zone) which was effected and formed by Palaeo-Pacific Ocean subduction from the Early–Middle Jurassic. However, Xu (2007) indicated that this gravity gradient zone was caused by the subduction of the Palaeo-Pacific Ocean Plate in the middle Early Cretaceous.

Thus, the differential evolution of basins and sedimentary palaeogeography between the eastern and western North China has initiated since the Early–Middle Jurassic. In fact, the eastern Heilongjiang Province located in the northeastern side of NE China was in a back-arc setting of the Palaeo-Pacific Ocean subduction under the East Asia Continent (Wu, 2007). Basin evolution, palaeogeography and dynamic mechanism of the Early–Middle Jurassic in northern North China and northeastern China were associated with the closure of the Okhotsk Ocean as well. Therefore, current researches suggest that the northern North China and northeastern China were in a back-arc environment of composite subduction of the Palaeo-Pacific Plate and the Okhotsk oceanic plate during the Early–Middle Jurassic (Xu et al., 2013; Safonova and Santosh, 2014). Hence, rising of the gravity gradient zone from Great Xing’an Range to Taihang Mountain is not only an indicator of beginning differentiated the palaeogeographic and tectonic evolution from east to west in North China, but also a crustal extension across the NCC in a large-scale and the maximum intensity. The Late Jurassic to the early Early Cretaceous strata were mainly volcanic–sedimentary assemblages and were characterized by bimodal-like volcanic rock associations. They rested on the unconformity induced by the Middle Jurassic Yanshan Orogeny and consisted of, in an ascending order, basic–intermediate volcanic rocks of basalt, basaltic andesite, trachyandesite and andesite, interbedded with lacustrine deposits of the Yanliao Biota-bearing Tiaojishan Formation, huge thick coarse-grained sediments of a combination of alluvial fan–fluvial conglomerates and sandstones containing local intermediate–acidic volcanic or volcaniclastic rocks of the Tuchengzi Formation, and acidic lavas and volcaniclastic rock associations of dacite and rhyolite and pyroclastic rocks of the Zhangjiakou Formation (Figure 3). The vast middle Early Cretaceous rifting volcanic and sedimentary rocks containing the Jehol Biota of younger than 130 Ma overlaid the Late Jurassic to the early Early Cretaceous volcanic–sedimentary strata.

### 3.3 Stage 3: Late Jurassic to early Early Cretaceous

During the early stage 3 (the middle Late Jurassic) (Figure 7), a variety of faulted basins occupied the Yinchuan–Yanshan areas because of regional extension. Faulted basins in the Yanshan Mountain were filled with sedimentary succession of massive intermediate–basic volcanic rocks (the Tiaojishan Formation) and the overlying purple-red, coarse-grained clastic rocks (the Houcheng Formation/ Tuchengzi Formation), which were not in co-occurrence with thrust faults regionally. Actually, through 154 Ma to 135 Ma, i.e., from the Late Jurassic to the early Early Cretaceous, there was vast thick purple-red coarse–fine-grained
Figure 3  Stratigraphy and evolution stages of the Mesozoic basins in North China (vertical line areas refer to the missing strata). Fm. = Formation; Gr. = Group; MMB = Manketoebi-Manitu–Baiyingaoao; MS = Mingshui; NJ = Neijiang; QSK = Qingshankou; SFT = Sifangtai; SJW = Sunjiawan; YJ = Yaojia; ZJG = Zhongjiangou.

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clastic deposits in North China. The Shishugou or Wuchaiwan Group in northern Xinjiang, NW China was both purple-red tuffaceous clastics with plenty of intercalations of conglomerates (165–164 Ma). Rare tuffaceous sediments except for purple-red coarse-fine-grained clastic deposits occurred in Gansu and Ningxia provinces, NW China. Faulted basins in the Yinshan Mountain were mainly filled with thick-layered alluvial–fluvial–lacustrine clastic sediments interbedded with freshwater limestone locally (Li et al., 2004). On the other hand, the Ordos Basin was filled with thick lacustrine–fluvial–alluvial fan deposits and frequent volcanic rocks, while thick conglomerates (the Fenfanghe Formation) consisting mainly of the Paleozoic or Triassic limestone dolomites and sedimentary rocks were deposited along the margin of the Ordos Basin.

However, the eastern Heilongjiang located at the active continental margin of the Palaeo-Pacific Plate (Xu et al., 2013; Safonova and Santosh, 2014) was dominated by the accretionary complex and ocean plate stratigraphy which consisted of gabbro, diabase, basic pillow lavas (basalt, spilite) and siliceous rocks, or exotic limestone blocks of the Late Paleozoic.

During the late stage 3 (the late Late Jurassic to early Early Cretaceous) (Figure 7), a giant rift system appeared along the Yanshan Mountain to the western Great Xing’an Range in NE China, the lithology of which mainly consisted of basic–intermediate volcanic rocks, middle–coarse-grained clastic rocks (the Houcheng Formation/Tuchengzi Formation/Emuerhe Group), and acid volcanic rocks with sedimentary rocks at top (the Zhangjiakou Formation and its equivalent) (Wang et al., 2006; Zhang et al., 2008, 2009, 2010, 2011; Ying et al., 2010).

Further, statistics of dating results of the Zhangjiakou Formation showed a minor discordant with previous results (Wang et al., 2006; Zhang et al., 2008, 2010). Current study indicates that acidic volcanic peak of the Zhangjiakou Formation is not only in an interval of 165–130 Ma but also in two peak pulses of 160–150 Ma and 140–130 Ma rather than 160–150 Ma and 141–122 Ma (Zhang et al., 2010) or simply 135 Ma as previously published research results (Wei et al., 2012). However, dating results of volcanism of the Zhangjiakou Formation suggest a 150–140 Ma weak peak being well consistent with the previous results (Zhang et al., 2010), which indicates the transformation of the Palaeo-Pacific Plate subduction, i.e., from a low angle subduction to slab rollback through the Jurassic to the Early Cretaceous (Wang et al., 2006; Zhang et al., 2008, 2009, 2010; Ying et al., 2010).
Figure 5  Basins and sedimentary palaeogeography of North China during the Late Triassic (early stage 2).

Figure 6  Basins and sedimentary palaeogeography of North China during the Early–Middle Jurassic (late stage 2). The previously unified Ordos–North China Basin was split into the two sub-basins of Ordos Basin and North China Basin during the late Early–Middle Jurassic.
Stratigraphic framework of Late Jurassic–early Early Cretaceous displays a regular variation from Yinshan–Yanshan Orogenic Belt to Great Xing’an Range, however, the Tiaojishan Formation is either missing or decreasing in thickness in western and northern Great Xing’an Range. On the contrary, the contemporary strata of the Tuchengzi Formation reaches a huge depositional thickness in northern Great Xing’an Range. In southern Great Xing’an Range and Yinshan–Yanshan Orogenic Belt, both the Tiaojishan Formation and the Tuchengzi Formation present a huge thick succession. However, thickness of the Zhangjiakou Formation and its contemporary strata in the whole Great Xing’an Range and western Yinshan–Yanshan Orogenic Belt is larger than those somewhere in North China.

At the same time, most of the eastern region of North China, in spite of giant rift systems, was a palaeogeographic highland named as the “East North China Highland”, which indicated a common geographic uplift and erosion. This study suggests that during stage 3, the regional tectonic setting, volcanics and magmas, sedimentary basins, and palaeogeographic evolution are not related to the composite subduction. In contrast, the North China was under post-orogenic extension which caused the collapse of the Mangolia–Okhotsk Orogenic Belt and the Yinshan–Yanshan Orogenic Belt (Fan et al., 2003).

3.4 Stage 4: middle–late Early Cretaceous

Furthermore, in North China, after intensive thrust and fold events at the end of stage 3, widespread extension reached its peak during stage 4 (Figures 8, 9) corresponding to lithospheric thinning and destruction of the NCC (Zhu et al., 2012a, 2012b). In sedimentary basins, the volcanic–sedimentary deposits accumulated either unconformably or conformably on the previous orogenic belts. Those medium- or large-scale basins were common on XMOB, which were mainly filled with fluvial and lacustrine deposits under hot and arid environments. Regional faulted basins with fluvial–lacustrine sediments and alkaline volcanic intercalations were, however, developed in the Beishan Mountain, Hexi Corridor, and Yinggen–Ejin–qi areas in northwestern China and Erlian regions on the northern side of North China. But, rift basins filled with intermediate volcanic rocks which were interbedded with fluvial–lacustrine sediments containing well-preserved fossils of the Jehol Biota were widely developed in the northern and northeastern China, the Far East of Russia, Mongolia, South Korea and Japan (Zhou et al., 2003; Matsukawa et al., 2006; Figure 8).

At the same time, the Tan-Lu striking-slipping fault led to basin formation within fault zone (i.e., in Hefei, eastern and western Shandong, northeastern Songliao and the Sanjiang Region). Typical pull-apart basins filled with thick volcanic–sedimentary rocks (the Qingshan and Dasheng Groups) appeared in the Yishu rift fault zone. Dinosaur bones and trace fossils were well preserved in shallow-lake sediments of the Dasheng Group. At that time, NE China was of the middle Early Cretaceous in age. Small-scale faulted basins were filled with basic volcanics and fluvial–lacustrine sediments. The Songliao Basin was a late Early Cretaceous giant lacustrine basin filled with deep-water lake (shale)–river facies sediments (Ren et al., 2002; Feng et al., 2010; Li et al., 2012b). Rift basins of the middle–late Early Cretaceous were characterized by marine–terrigenous sediments and interbedded with calc-alkaline volcanic rocks in Sanjiang Region as well. Here, the river system connected with the Palaeo-Pacific Ocean and palaeoclimate was mainly warm and humid (Sha, 2007; Figure 9).

3.5 Stage 5: Late Cretaceous

During stage 5 (the Late Cretaceous), a series of broad basins with fluvial to shallow lacustrine facies occurred in the Hexi Corridor, including the Yinggen–Ejin–qi Basin which was located in NW China and the Erlian Basin which was located in the northern region of North China (Figure 10). The Songliao Basin and the Sanjiang faulted (rift) basin groups continued their spreading. At this period, basins and palaeogeography of North China and its northeastern region were obviously effected by the striking-slipping movement of the Tan-Lu Fault.

Actually, since the Late Mesozoic, from the western side of Great Xing’an Range through the Songliao Basin to the Sanjiang Region of Heilongjiang, sedimentary basins distributed gradually towards the southeast of NE China, which reflected the influence of the Palaeo-Pacific continental margin evolution (Wang et al., 2006). In addition, during the Late Mesozoic, terrestrial biota represented by flourishing dinosaur fauna prevailed in North China and the North–East Asia, including the Middle–Late Jurassic Yanliao Biota and the middle–late Early Cretaceous Jehol Biota characterized by terrestrial plants and animals, feathered dinosaurs, primitive birds, mammals, insects, and angiosperms (Zhou et al., 2003; Liu et al., 2012).

In general, during the Late Mesozoic, the eastern China and the northeastern Asia, South Korea, Japan and the Far East of Russia all shared the same tectonic, palaeogeographic and palaeoecological environments, which was habitable for terrestrial vertebrate and invertebrate faunas
Figure 7  Basins and sedimentary palaeogeography of North China from the Late Jurassic to the early Early Cretaceous (stage 3).

Figure 8  Basins and sedimentary palaeogeography of North China during the middle Early Cretaceous (early stage 4).
Figure 9  Basins and sedimentary palaeogeography of North China during the late Early Cretaceous (late stage 4).

Figure 10  Basins and sedimentary palaeogeography of North China during the Late Cretaceous (stage 5).
4 Conclusions

In North China, terrestrial sedimentary palaeogeography and tectonic settings can be classified as five evolutionary stages for the Mesozoic basins. During the Early Mesozoic, the XMOB was in a post-orogenetic setting; afterwards it was uplifted and supplied sediments to the Ordos–North China Basin.

Following the initial extension of the Middle Triassic, more intensive expansion and a series of faulted basins occurred during the period from the Late Triassic to the Early–Middle Jurassic. In addition, small-scale, basic-intermediate volcanic rocks and clastic rocks associated with coal-bearing sediments were widely distributed in the northeastern region of North China at that period. However, to the west, volcanic rock intercalations were rare. An active continental margin with accretionary prism developed on the eastern side of Heilongjiang due to subduction of the Palaeo-Pacific Plate.

At the end of the Early–Middle Jurassic, the Yanshanian orogeny occurred, which was characterized by complicated thrusts and folds and led to differential basin evolutions and sedimentary palaeogeography between the eastern and western regions of North China.

During the transitional period of the Late Jurassic–Early Cretaceous, the northern and northeastern regions of North China were in an extensional tectonic setting accompanied with vast collapse of both the Okhotsk Orogenic Belt and the Yanshan tectonic belt. A tectonic zone which was filled with basic–acidic lavas, pyroclastic rocks and thick-layered, coarse-grained sediments related to the northeastern Asia rift system was extended from the Yanshan Mountain to the Great Xing’an Range.

Furthermore, from the Middle to Late Cretaceous, riftbasins in North China developed regionally, especially along the Tan-Lu Fault Zone. The northeastern region of North China was characterized by the occurrence of the Songliao Basin and the Sanjiang Basin groups, both of which were in a lacustrine environment.

In addition, terrestrial biotas (i.e., the Yanliao Biota of the Middle–Late Jurassic) and the Jehol Biota of the middle–late Early Cretaceous (which mainly consists of feathered dinosaurs, primitive birds, mammals, reptiles, pterosaurs, insects and plants/angiosperms, etc.) dominated in North China and northeastern Asia during the Late Mesozoic. At this period, the East China, Korean Peninsula, Japan and the Far East of Russia shared same palaeo-geographic and palaeoecologic environments, which were habitable for terrestrial vertebrate and invertebrate faunas and floras.

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