Zircon U-Pb dating of the Lower Cretaceous strata on the margin of the Erlian Basin, North China and its Constraints on basin evolution

Ying Li1,3, Yinhang Cheng1,2, Shaoyi Wang1, Tianfu Zhang1, Xuejian Teng1 and Yanfeng Li1

1Tianjin Center, China Geological Survey, Tianjin 300170, China;
2China University of Geosciences (Beijing), Beijing 100083, China
3E-mail: liying270@163.com

Abstract. A large number of Early Cretaceous magmatic rocks are exposed in the Erlian Basin in North China. LA-MC-ICP-MS zircon U-Pb dating of rhyolites with age of 122.8 ± 0.4 Ma is corresponded to basin subsidence, reflecting a large-scaled extension event occurred in North China. There was a structural inversion after the Neogene, which caused the migration of the Erlian Basin center from the NW to SE, with the center of the Early Cretaceous basin corresponding with the NW margin of the modern basin.

1. Introduction
The Cretaceous terrestrial deposits widely distributed in the hinterlands of East Asia are famous for their abundant mineral resources, such as oil, coal, gas, and terrestrial plant fossils, and have long attracted geological interest[1-3]. In North China, Early Cretaceous magmatic activity was intensive, with abundant coeval intrusive and volcanic rocks emerging, indicating extensional tectonics[4-6]. However, the sedimentary setting of the Erlian Basin and the response to this extension event in the Early Cretaceous are controversial.

Since the late carboniferous, the Erlian area has been in an extensional phase and a wide spread extension dominated northeast China during the Late Mesozoic, with rifting, magmatism, and exhumation of metamorphic core complexes across broad areas[7-8]. The Erlian Basin experienced extensive rifting during this phase, but its sedimentary setting is controversial.

In this study, we identified the rhyolites from the Lower Cretaceous strata in the Erlian Basin. It is concluded that a large-scale extension event, which resulted in the formation of the Cretaceous basin, occurred in the Erlian area in North China during the Early Cretaceous.

2. Geological background
With a 10 × 104 km² area and a location at the northern margins of North China, the Erlian Basin is a large-scale Mesozoic rift-related basin[9]. Due to the Quaternary coverage, there is a slight glutenite lying in angular unconformity upon the Late Paleozoic sequences and distributed on the margin of the basin (Figure 1). The rhyolites of the Early Cretaceous are exposed in the east of the study area and the Lower Cretaceous stratum in the basin is the Damoguaihe Formation.
Results and discussions

One sample of Cretaceous rhyolite was collected for U-Pb zircon dating. Twenty-two U-Pb isotope analyses on 23 zircon grains were obtained from the rhyolite. The analyzed grains were mostly euhedral and colorless, with typical magmatic rhythmic banding and oscillatory zoning. These zircons have highly variable abundances of Th (102-1081 ppm) and U (25-203 ppm), with high Th/U ratios of 0.13-0.55. Twenty data were plotted on or near the concordia curve (Figure 2) and yielded $^{206}\text{Pb} / ^{238}\text{U}$ ages within $(122 \pm 1) - (125 \pm 1)$ Ma. The weighted mean $^{206}\text{Pb} / ^{238}\text{U}$ age of the samples based on the twenty analyses was $122.8 \pm 0.4$ Ma (MSWD = 0.8) (Table 1).
Table 1. LA-MC-ICP-MS U-Th-Pb isotopic data for zircon grains of rhyolite on the margin of Erlian Basin.

| Spots | U, Th content and ratio | Isotopic ratios | Age(Ma) |
|-------|------------------------|----------------|---------|
|       | U (ppm) | Th (ppm) | Th/U | 206Pb/238U±1σ | 207Pb/235U±1σ | 207Pb/206Pb±1σ | 206Pb/238U±1σ | 207Pb/235U±1σ |
| 3098.1 | 750 | 128 | 0.17 | 0.0192 | 0.0001 | 0.1573 | 0.0030 | 0.0593 | 0.0010 | 123 | 1 | 148 | 3 |
| 3098.2 | 130 | 36 | 0.28 | 0.0192 | 0.0001 | 0.1326 | 0.0095 | 0.0500 | 0.0036 | 123 | 1 | 126 | 9 |
| 3098.3 | 270 | 67 | 0.25 | 0.0191 | 0.0001 | 0.1440 | 0.0041 | 0.0545 | 0.0015 | 122 | 1 | 137 | 4 |
| 3098.4 | 104 | 25 | 0.24 | 0.0196 | 0.0002 | 0.1526 | 0.0137 | 0.0565 | 0.0051 | 125 | 1 | 144 | 13 |
| 3098.5 | 462 | 183 | 0.40 | 0.0192 | 0.0001 | 0.1443 | 0.0032 | 0.0545 | 0.0012 | 123 | 1 | 137 | 3 |
| 3098.6 | 115 | 40 | 0.35 | 0.0194 | 0.0002 | 0.1334 | 0.0148 | 0.0498 | 0.0055 | 124 | 1 | 127 | 14 |
| 3098.7 | 487 | 97 | 0.20 | 0.0192 | 0.0001 | 0.1337 | 0.0033 | 0.0505 | 0.0012 | 123 | 1 | 127 | 3 |
| 3098.8 | 945 | 257 | 0.27 | 0.0193 | 0.0001 | 0.1438 | 0.0014 | 0.0541 | 0.0005 | 123 | 1 | 136 | 1 |
| 3098.10 | 766 | 128 | 0.17 | 0.0192 | 0.0001 | 0.1375 | 0.0022 | 0.0520 | 0.0008 | 123 | 1 | 131 | 2 |
| 3098.11 | 212 | 28 | 0.13 | 0.0192 | 0.0001 | 0.1338 | 0.0058 | 0.0504 | 0.0021 | 121 | 1 | 127 | 6 |
| 3098.12 | 104 | 34 | 0.33 | 0.0192 | 0.0001 | 0.1425 | 0.0089 | 0.0538 | 0.0034 | 123 | 1 | 135 | 8 |
| 3098.13 | 213 | 83 | 0.39 | 0.0192 | 0.0001 | 0.1300 | 0.0060 | 0.0492 | 0.0023 | 122 | 1 | 124 | 6 |
| 3098.14 | 176 | 42 | 0.24 | 0.0194 | 0.0001 | 0.1348 | 0.0072 | 0.0508 | 0.0027 | 123 | 1 | 128 | 7 |
| 3098.15 | 220 | 33 | 0.15 | 0.0194 | 0.0001 | 0.1300 | 0.0048 | 0.0486 | 0.0017 | 124 | 1 | 124 | 5 |
| 3098.16 | 841 | 128 | 0.17 | 0.0192 | 0.0001 | 0.1375 | 0.0058 | 0.0504 | 0.0021 | 123 | 1 | 127 | 6 |
| 3098.18 | 102 | 22 | 0.22 | 0.0204 | 0.0002 | 0.1490 | 0.0119 | 0.0530 | 0.0042 | 130 | 1 | 141 | 11 |
| 3098.19 | 561 | 103 | 0.18 | 0.0193 | 0.0001 | 0.1446 | 0.0029 | 0.0545 | 0.0011 | 123 | 1 | 137 | 3 |
| 3098.20 | 392 | 86 | 0.22 | 0.0194 | 0.0001 | 0.1351 | 0.0031 | 0.0495 | 0.0012 | 123 | 1 | 125 | 3 |
| 3098.21 | 237 | 59 | 0.25 | 0.0194 | 0.0001 | 0.1335 | 0.0072 | 0.0499 | 0.0026 | 124 | 1 | 127 | 7 |
| 3098.22 | 1081 | 203 | 0.19 | 0.0190 | 0.0001 | 0.1504 | 0.0060 | 0.0565 | 0.0013 | 122 | 1 | 129 | 2 |
| 3098.23 | 237 | 59 | 0.25 | 0.0194 | 0.0001 | 0.1335 | 0.0072 | 0.0499 | 0.0026 | 124 | 1 | 127 | 7 |
| 3098.24 | 343 | 56 | 0.17 | 0.0202 | 0.0002 | 0.1533 | 0.0116 | 0.0503 | 0.0038 | 141 | 1 | 145 | 11 |

All data are analyzed at Tianjin Center, China Geological Survey, Tianjin, China. All errors are quoted as 1σ level.

1-Quercoidites; 2-Juglanspollenites; 3-Cupuliferoipollenites; 4-Betulaceoipollenites; 5-Sorbaria; 6-Cotinus; 7-Ginkgoaceae; 8-Pinuspollenites; 9-Piceites; 10-Cycadarpollenites; 11-Liquidambarpollenites; 12-Tsuga; 13-Cryptomeriapollenites; 14-Chekingensis; 15-Ephedripites; 16-Chenopodipollis; 17-Cruciferae; 18-Gramineae; 19-Typhapollis; 20-Artemisiaepollenites;21-Rubia; 22-Agriophyllum; 23-Hyoscyamus; 24-Humulus; 25-Urticaceae; 27-Lilacidites; 28-Orchophragmus; 29-Pterisiporites; 30-Polypodiaceaesporites; 31-Lygodiumsporites; 32-Cyathidites; 33-Selaginellaceae; 34-Araiostegia; 35-Plagiogyriaceae; 36-Hymenophyllaceae; 37-Laevigatosporites; 38-Triletes; 39-Ceratopteris; 40-

Figure 2. CL images(a) and Zircon U-Pbage(b) from rhyolites.

The ages of 122.8 ± 0.4 Ma examined in this paper were determined via U-Pb dating, which reflects the early Cretaceous magmatic activity on the Erlian Basin.

There are many Early Cretaceous magmatic rocks on the Erlian Basin margin, which are correlated with tectonic subsidence[10-11]. Recent studies have shown that the zircon ages of these rocks are around128-111Ma[11]. In this paper, we obtained a weighted mean age of 122.8 ± 0.4 Ma of the rhyolite on the Erlian Basin margin, which might correlate with the same age as basin subsidence.

Since the late carboniferous, the area has been in an extensional phase[2]. Widespread extension dominated northeast China during the Late Mesozoic, with rifting, magmatism, and exhumation of
metamorphic core complexes across broad areas [8,10]. The Erlian Basin experienced extensive rifting during this phase, but its subsequent evolution is controversial.

Based on data from seismic reflection and gravity analysis in this paper, on part of the SE margin of Erlian Basin, a large-scale Early Cretaceous shear zone developed, showing a left-lateral slit shear zone and deformation granites with zircon U-Pb ages of 135.9 ± 1.2 Ma and 130.0 ± 0.5 Ma[10]. This indicates that there was an extensional event after about 130 Ma, which caused the tectonic subsidence and uplift corresponding with the coupling of the basin and range. The many synchronal acid volcanics[5,7] on the margin of the basin are also indicative of an extensional event during the Early Cretaceous. After the Neogene, there was a structural inversion, which caused the migration of the Erlian Basin center from the NW to SE.

4. Conclusions

(1) The Damoguaihe Formation has the Early Cretaceous age of 122.8 ± 0.4 Ma from the rhyolite on the margin of the Erlian Basin.

(2) Combined with seismic and gravity interpretation and the borehole data, the Erlian Basin was a lateral extent half-graben in the Early Cretaceous. There was a structural inversion after the Neogene, which caused the migration of the Erlian Basin center from the NW to SE, with the center of the Early Cretaceous basin corresponding with the NW margin of the modern basin.

Acknowledgments

This work was supported by the 973 Program (2015CB453000) and the China Geological Survey Program (DD20190813 and 1212011120697).

References

[1] Deng Shenghui 2002 Ecology of the Early Cretaceous ferns of Northeast China _Cretaceous Research_ **119** 93-112

[2] Wang Shuqing, Hu Xiaojia, Zhao Hualei 2019 Geochronology of Late Carboniferous alkaline granite from Honger area, Sunidzuqi Inner Mongolia _Geological Survey and Research_ **42(2)** 81-85

[3] Zhang Mingzhen, Dai Shuang, Pan Baotian, Wang Lubo, Peng Dongxiang, Wang Huawei and Zhang Xiang 2014 The palynoflora of the Lower Cretaceous strata of the Yingen-Ejinaqi Basin in North China and their implications for the evolution of early angiosperms. _Cretaceous Research_ **48** 23-38

[4] Jahn, B.M., Wu Fuyuan, Capdevila, R. Martineau, F., Zhao Zhenhua and Wang Yixian 2001 Highly evolved juvenile granites with tetrare REE patterns: the Wuduhe and Baerzhe granites from the Great Xing’an Mountains in NE China. _Lithos_ **59** 171-198

[5] Meng Qingren 2003 What drove Late Mesozoic extension of the Northern China-Mongolia tract? _Tectonophysics_ **369** 155-174

[6] Liu Wei, Siebelb, W., Li Xinjun and Pan Xiaofei 2005 Petrogenesis of the Linxigranitoids, northern Inner Mongolia of China: constraints on basaltic underplating _Chemical Geology_ **219** 5-35

[7] Cheng Yinhang, Teng Xuejian, Li Yanfeng, Yang Junquan, Liu Yang, Peng Lina, Li Ying and Li Min 2014 Chronology constraint and tectonic evolution of Hanwula Early Cretaceous ductile shear belt in Dong Ujimqin, Inner Mongolia. _Earth Science—Journal of China University of Geoscience_ **39** 375-386

[8] Wu Fuyuan, Lin Jingqian, Wilde, S.A., Zhang Xiaou and Yang Jinhui 2005 Nature and significance of the Early Cretaceous giant igneous event in eastern China. _Earth and Planetary Science Letters_ **233** 103-119

[9] Wu Yueyong, Jiang Haijiao, Kou Shuai 2016 Geochemical characteristics of Early Cretaceous volcanic rocks in Qagan Obo area, SonidLeft Banner, Inner Mongolia _Geological Survey and Research_ **39(1)** 1-14
[10] Cheng Yinhang, Teng Xuejian, Li Yanfeng, Yang Junquan, Peng Lina, Li Ying and Liu Yang 2014 Geochronology, Geochemistry and Geological Significance of Felsic Volcanic Rocks in Haimosaige Area. *Acta Petrologica ET Mineralogica* **33** 211-225

[11] Zhang Jiheng, Ge Wenchun, Wu Fuyuan and Liu Xiaoming 2006 Northwest Mesozoic bimodal volcanic suite in Zhalantun of the Da Hinggan Range and its geological significance: zircon U-Pb age and Hf isotopic constraints. *ACTA Geological Sinica (English edition)* **8** 58-69