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The SHRIMP U-Pb isotope dating of Mesozoic volcanic from Zhangwu-Heishan Area, West Liaoning Province, China

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ABSTRACT

The Zhangwu-Heishan area is located in the east of the Fuxin-Yixian basin. Besides the Quaternary soil, the study area is mostly covered with volcanic rock. The horizon and age of volcanic rock play an essential role in understanding fossil beds, structures, and sedimentary evolution of West Liaoning Province and coal seeking. During this work, 11 volcanic rock samples were measured by SHRIMP U-Pb isotope analysis. Based on the reported data on the age of the Mesozoic volcanic rock in West Liaoning Province, in combination with new measurement data, Cretaceous volcanic activities in West Liaoning Province can be divided into five stages, namely 132±1 Ma, 126±1 Ma, 122±2 Ma, 115±2 Ma, and 100±5 Ma. Based on statistical results, this paper concluded that the thinning time of the crust in Northeast China is from 132±1 Ma to 115±2 Ma.

Keywords: West Liaoning Province; Zhangwu-Heishan Area; Mesozoic Volcanic Rock; Isotopic Age; Geological Significance.

Datación isotópica U-Pb a través de la Microsonda de Iones de Alta-Resolución en rocas volcánicas del Mesozoico para el área Zhangwu-Heishan, en la provincia de Liaoning, en el occidente de China

RESUMEN

El área Zhangwu-Heishan se ubica en el este de la cuenca Fuxin-Yixian. El suelo del Cuaternario en el área de estudio está cubierto por rocas volcánicas. El horizonte y la edad de la roca volcánica juegan un rol esencial en la comprensión de las capas fósiles, las estructuras y la evolución sedimentaria de la Provincia Liaoning, en el occidente de China, y en la búsqueda de carbón. En este trabajo se estudiaron 11 muestras de roca volcánica a través del análisis isotópico Shrimp U-Pb (Datación U-Pb a través de la Microsonda de Iones de Alta-Resolución). De acuerdo con la información reportada en las rocas volcánicas de edad del Mesozoico al oriente de la provincia Liaoning, en combinación con información de nuevas mediciones, las actividades volcánicas del Cretácico en la zona se pueden dividir en cinco etapas: 132±1 Ma, 126±1 Ma, 122±2 Ma, 115±2 Ma, y 100±5 Ma. Con base en los resultados estadísticos, este estudio concluyó que el tiempo de adelgazamiento de la corteza en el noroeste de China está entre 132±1 Ma y 115±2 Ma.

Palabras clave: Provincia Liaoning; área Zhangwu-Heishan; rocas volcánicas del Mesozoico; edad isotópica; significancia geológica.

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Introduction

Due to the discovery of precious fossils, West Liaoning Province has been drawing extensive interests in recent years (Chen et al., 1998; Sun, 1998; Swisher, 1999; Xu, 2001; Zhou, 2003; Zhou, 2003). Meanwhile, the researches on the stratigraphy, paleo-geography, paleoclimate, and paleomagnetism of the Mesozoic volcano-sedimentary basin in west Liaoning Province are gradually performed (Pan et al., 2001; Zhang et al., 2002; Zhu et al., 2001 & 2002; Gong et al., 2007; Li et al., 2002; Ren, 1997). As an essential terrane in North China where Meso-Cenozoic volcanic activities were developed, outstanding achievements have also been made in the researches on the chronology (Figure 1) and geochemistry of volcanic rock in west Liaoning Province (Jia et al., 1999; Zhou, 2001; Zhang & Zheng, 2003; Yang, 2007; Wu et al., 2003). Whereas SHRIMP Zircon U-Pb isotopic dating of volcanic rock in west Liaoning Province mainly concentrates on Yixian Basin, there are only sporadic isotopic reports dating of volcanic rock in Zhangwu-Heishan Area (Chen et al., 1997; Huang, 2006 & 2007; Xiao, 2008).

West Liaoning Province is located in the east section of the Yanshan Platformal Fold Belt in the north of Sino Korean Paraplatform and belongs to the east extension of Yanshan Orogenic Belt (Figure 1). Yanshan Orogenic Belt lies inside the North China Platform and has experienced intense tectonic deformation, magmatic and volcanic activities, and syn-orogenic sedimentation Jurassic-Cretaceous Yanshan Movement, and finally becomes a typical intraplate orogenic belt (Zhang CH, 1999) far away from any contemporary plate boundary. The subduction of the Pacific Plate has resulted in NE-trending thrust nappe structure of late Jurassic Epoch and extensional structure of the early Cretaceous Epoch. Before the Mesozoic Period, the study area is a large tectonic uplift area. At the first stage of the Yanshan Movement, the fault-folding formed lower-middle Jurassic Series in the NNE-trending depression area, including coal-bearing strata - Beipiao Formation. At the Yanshan Movement's medium setting, a large-scale fracture occurred and was accompanied by a magmatic eruption, and then a Mesozoic tectonic framework was formed.

Denomination and Age of Volcanic Rocks

Although numerous detailed stratigraphic researches have been carried out in West Liaoning Province, the knowledge of stratigraphic sequence, the horizon of volcanic rock, and volcanic eruption periods are unified yet. For instance, whether volcanic rock in Yixian Formation is of late Jurassic Epoch (Wang, 1987; Ren et al., 1997; Wang, 1998; Luo et al., 1999), late Jurassic to early Cretaceous Epoch (Zhang et al., 1992; Chen et al., 1998; Ji et al., 1998; Sun & Zheng, 2000; Jiang et al., 2000; Wang et al., 2002) or early Cretaceous Epoch (Li et al., 2001; Wang et al., 1999; Wang et al., 2001; Xu et al., 1999; Ji et al., 2002; Wang et al., 2005; Zhang et al., 2006) is an open question. For more details of the stratal division in this area and volcanic rock's denomination, see the references Wang et al., 2004; Cai, 2009). It should be noted that the Scientific Research Institute of Liaoning Bureau of Coalfield Geological Exploration (1970) advocates that extensive volcanic rock in this area belongs to Dalinghe Formation and is of Cretaceous Epoch and concluded that there might be coal seams of Fuxin Formation under this suite of volcanic rock. Likewise, the 107th Coalfield Geological Brigade of Liaoning Province held in 1974 suggested that coal-bearing series of Badaohao Formation could not be correlated with Shahai Formation or Fuxin Formation in Fuxin Basin, and Gangtaishan volcanic rock overlies Badaohao Formation and also drew the conclusion that the coal possibly could be found below those volcanic rocks.

Isotopic Dating and Eruption Period of Volcanic Rock

Isotopic dating of volcanic rock in west Liaoning Province starts in the 1980s (Diao, 1983; Wang, 1984 & 1985). Some fundamental findings have been made since the 1990s (For the data on isotopic dating, see Figure 2). By far, over 120 pieces of data derived from various dating methods have been published. These data are systematically collected, and the distribution map (see Figure 2) was plotted in this work. From the figure, the age of volcanic rock

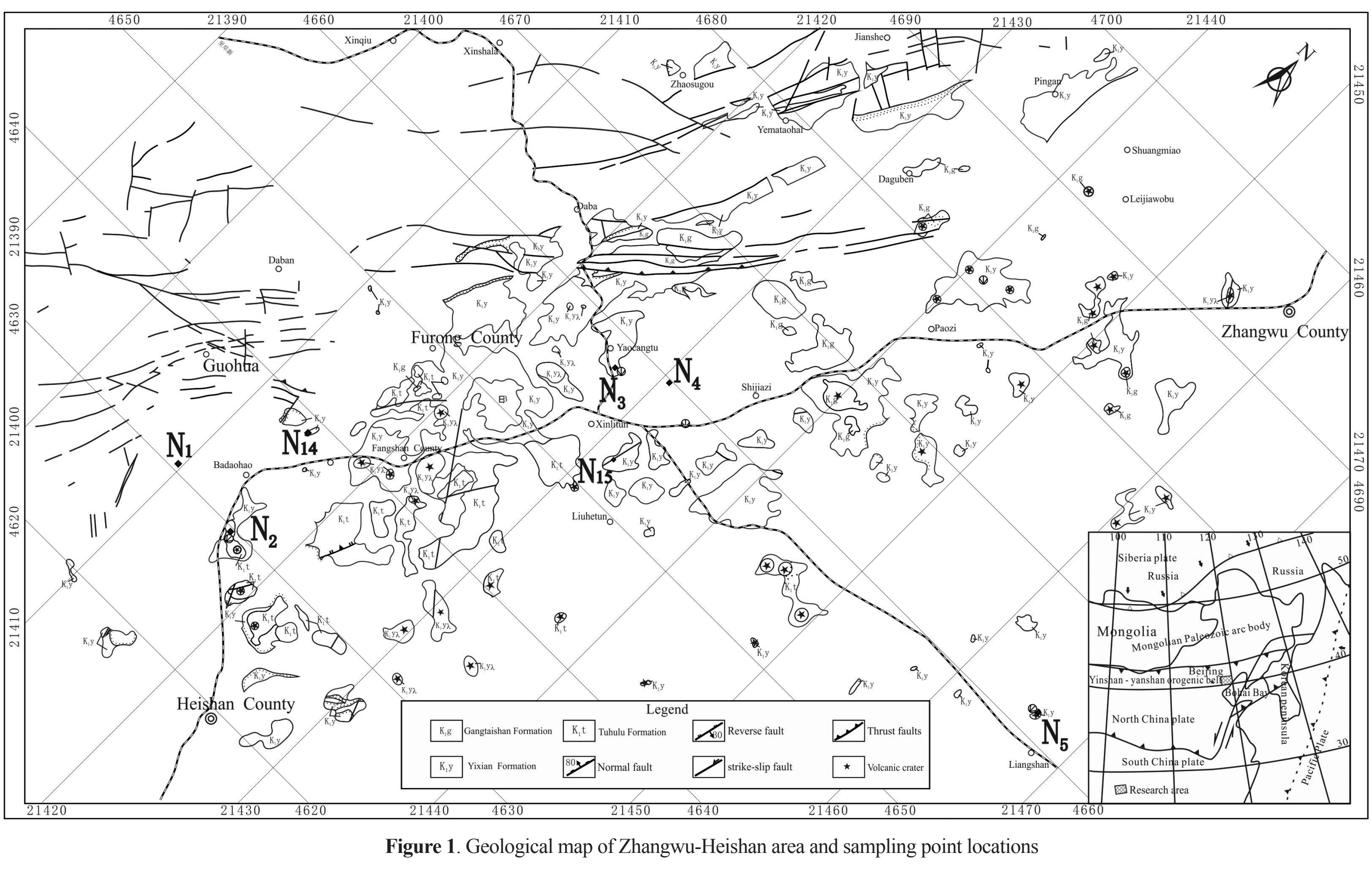

Figure 1. Geological map of Zhangwu-Heishan area and sampling point locations

which crops out in west Liaoning Province varies between 56 Ma and 147 Ma. Yixian Formation of early Cretaceous Epoch in the Yixian Basin contains four suites of volcanic rock and sedimentary rock (Ji, 2004), which represent four volcanic-sedimentary activities. As shown in Table 1, the periods of volcanic activities are 132±1 Ma, 126±1 Ma, 122±2 Ma, and 115±2 Ma. Also, a suite of alkaline basalt was formed in the period of 90-105 Ma. This is identical to the east part of North China (Zhai et al., 2003). There is also a Paleogene olivine-inclusion-bearing basalt suit with the age of about 56Ma in the Zhangwu-Heishan Area. In 2008 the International Commission on Stratigraphy adjusted the Jurassic-Cretaceous boundary from originally 135 Ma (140 Ma) to 145 Ma±4 Ma and the age of lower Cretaceous–upper Cretaceous limit from 95 Ma to 99.6 Ma. Therefore, previously delineated volcanic rock of late Jurassic Epoch is now of early Cretaceous Epoch, and the peak period of volcanic activities is the medium stage (130 Ma-122 Ma or so) of early Cretaceous Epoch, namely Barremian to Aptian stage.

It is an indisputable fact that the lithospheric mantle in North China Craton was thinned on a large scale in the Mesozoic and Cenozoic Periods (Gao et al., 2004; Liu et al., 2004). The earth's crust in west Liaoning Province was also thinned when volcanic rock in the Yixian Formation was formed (Zhang, 2003; Zhang, 2005). The time when Yixian Formation was formed is also the critical period when the earth's crust (lithosphere) in Northeast China was thinned, so the age of top and bottom boundaries of volcanic rock in Yixian Formation is the critical period when the earth's crust (lithosphere) in west Liaoning Province, even Northeast China, was thinned.

Conclusions

The horizon and age of volcanic rock play an essential role in understanding fossil beds, structures, and sedimentary evolution of West Liaoning Province and coal seeking. During this work, 11 volcanic rock samples were measured by SHRIMP U-Pb isotope analysis. Based on the reported data on the age of the Mesozoic volcanic rock in West Liaoning Province, in combination with new measurement data, Cretaceous volcanic activities in West Liaoning Province can be divided into five stages, namely 132±1 Ma, 126±1 Ma, 122±2 Ma, 115±2 Ma, and 100±5 Ma. Based on the statistical result, this paper concluded that the thinning time of the crust in Northeast China is from 132±1 Ma to 115±2 Ma.

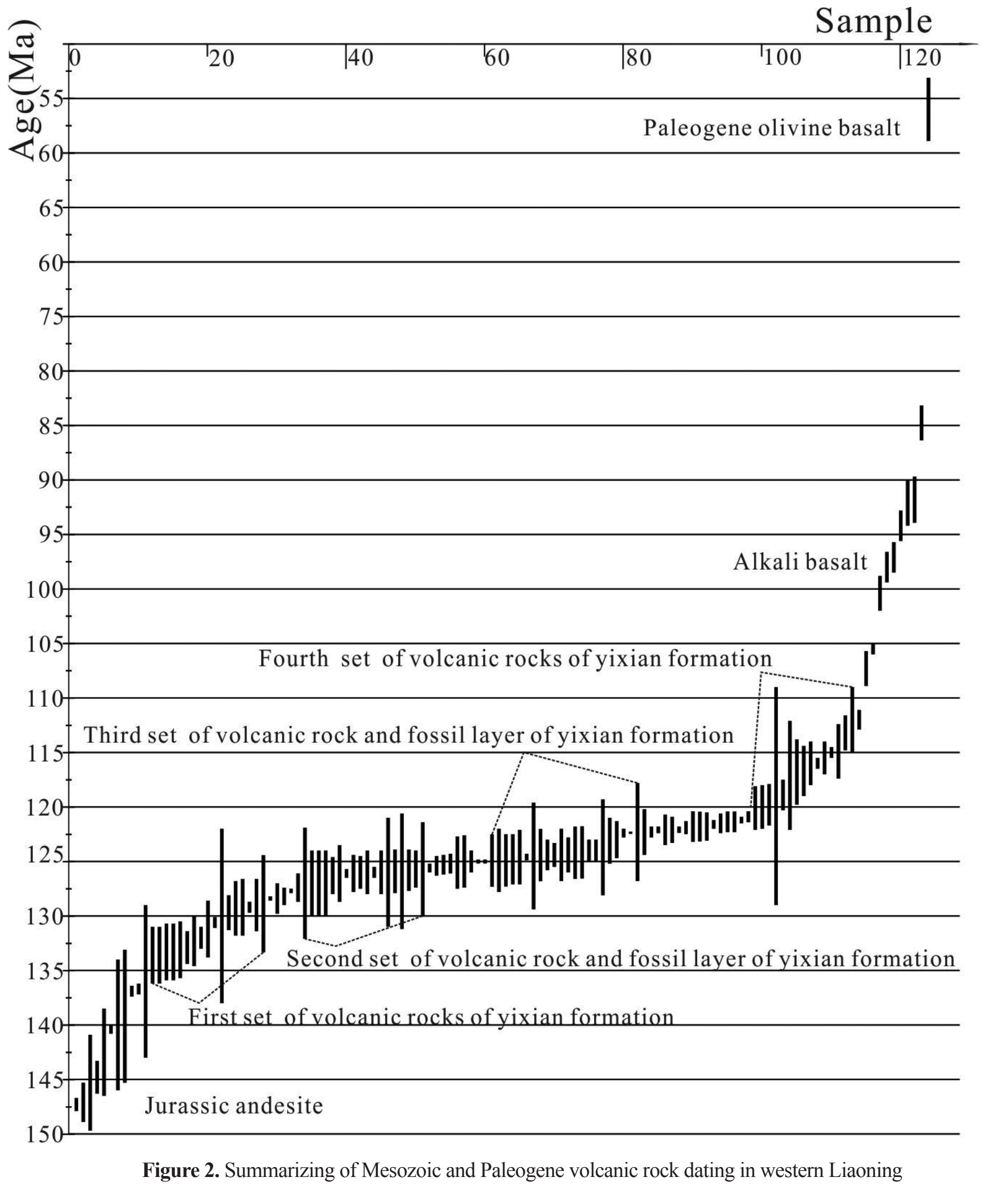

Figure 2. Summarizing of Mesozoic and Paleogene volcanic rock dating in western Liaoning

Note: Data source includes: Diao, N. C.; Wang, D. F.; Guo, H.Z.; Zhang, Z.C.; Smith; Li, P. X.; Wang, S. S.; Luo, Z. K.; Wang, D. Y.; Zhu, R. X.; Zhu, Q. J.; Zhang, X. H.; Peng, Y. D.; Zhang, H. F.; Zhen, J. P.; Wang, W. L.; Ji, Q.; Yang, W.; Zhang, H.; Li, D. M.; Huang, H.; Shao, J. A.; Xiao, G. Q.; Wang, Q. L.; Meng, F. X., and this paper.

Table 1. Rock samples and dating results of volcanic in Fuxin and Heishan-Zhangwu area

NO	Sample Location	Lithology	Test method	Age/Ma	Data source
1	Zhuanchengzi in Yixian	andesite, basalt	K-Ar	139.2±6.1	Diao et al.
2	Zhuanchengzi in Yixian	andesite, rhyolite	K-Ar	117.1±5	Diao et al.
3	Zhuanchengzi in Yixian	andesite	Rb-Sr	125.9±5.3	Wang et al.
4	Zhuanchengzi in Yixian	basalt-basaltic andesite	K-Ar	136.9	Wang et al.
5	Zhuanchengzi in Yixian	rhyolite	Rb-Sr	142.5±4	Wang et al.
6	Wendi Countryside	rhyolite	Rb-Sr	126±5	Wang et al.
7		rhyolite, andesite	Rb-Sr	127±3	Guo et al.
8	Dakangbo in Yixian	andesite, dacite	Rb-Sr	127.0±3	Zhang et al.
9	Jingangshan in Yixian	dolerite	Ar-Ar	120.8-121	Smith et al
10	Jiashangou in Beipiao	basalt	Ar-Ar	121.2±0.3	Smith et al
11	Huanghuashan in Yixian	volcanic breccia	Ar-Ar	121.5±0.9	Smith et al
12	Zoujiagou in Yixian	basalt	Ar-Ar	121.6±0.4	Smith et al
13	Central Yixian Formation	zircon	U-Pb	136.7	Luo et al.
14	Yixian	andesite	Ar-Ar	129.2	Chen et al.
15	Zhuanchengzi in Yixian	phosphorite	U-Pb	136±7	Chen et al.
			Rb-Sr	130±8	Chen et al.
16	Hejiagou in Yixian	andesite	Ar-Ar	119.0±10.0	Chen et al.
17	Zhujiagou in Yixian	andesite	Ar-Ar	124.5±4.9	Chen et al.
18	Dehuiyingzi in Zhangwu	trachyandensite, dacite	Ar-Ar	123.7±4.4	Chen et al.
19	Dingjiafang in Zhangwu	andesite	Ar-Ar	125.9±2.0	Chen et al.
20	Yemaotai in Zhangwu	dacite	Ar-Ar	112.0±0.9	Chen et al.
21	Yemaotai in Zhangwu	andesite	Ar-Ar	115.0±0.5	Chen et al.
22	Paozi in Fuxin County	Hyalinite andesite	U-Pb	116	Chen et al.
23	Sihetun, Jiashangou	tuff	Ar-Ar	145.3±4.4	Luo et al.
24	Sihetun, Jiashangou	tuff	Ar-Ar	144.8±1.5	Luo et al.
25	Sihetun, Jiashangou	tuff	Ar-Ar	147.1±1.8	Luo et al.
26	Fuxin	basalt	K-Ar	84.76±1.6	Zheng et al.
27	Sihetun	Tuff permeates feldspar	Ar-Ar	124.6±0.3	Swisher et al
28	Sihetun	Tuff permeates feldspar	Ar-Ar	125.0±0.18	Swisher et al
29	Hengdaozi	sanidine	Ar-Ar	125.0±0.19	Swisher et al
30	Dijiagou	trachyte	Ar-Ar	147.3±0.6	Li et al.
31	Dijiagou	trachyandensite	Ar-Ar	140.4±0.4	Li et al.
32	Xijianshan Section	andesite	Ar-Ar	121.9±0.6	Li et al.
33	Xijianshan Section	dolerite	K-Ar	116.7±2.3	Li et al.
34	Jingangshan in Yixian	andesite	K-Ar	120.1±2.0	Li et al.
35	Xiaoyantun in Yixian	basalt	K-Ar	91.81±2.13	Li et al.
36	Xiaoyantun in Yixian	andesite	K-Ar	125.6±0.4	Li et al.

(*Continued*)

Table 1. Rock samples and dating results of volcanic in Fuxin and Heishan-Zhangwu area

NO	Sample Location	Lithology	Test method	Age/Ma	Data source
37	Dijiagou—Zhuanchengzi	basalt	K-Ar	131.2±2. 6	Wang et al.
38	Sihetun	tuff	U-Pb	125.2±0.9	Wang et al.
39	Sihetun	basaltic andesite	Ar-Ar	128.2±0.8	Wang et al.
40	Sihetun	basaltic andesite	Ar-Ar	128.4±1.4	Wang et al.
41	Sihetun	basaltic andesite	Ar-Ar	128.4±0.2	Wang et al.
42	Sihetun	dolerite	Ar-Ar	122.3±0.5	Wang et al.
43	Sihetun	dolerite	Ar-Ar	122.1±1.2	Wang et al.
44	Sihetun	dolerite	Ar-Ar	121.8±1.3	Wang et al.
45	Paishanlou in Fuxin	dioritic porphyrite	U-Pb	126±2	Luo et al.
46	Paishanlou in Fuxin	granite porphyry	U-Pb	124±1	Luo et al.
47	Paishanlou in Fuxin	dioritic porphyrite	U-Pb	125±1	Luo et al.
48	Dashitougou in Fuxin	biotite granite	U-Pb	124±1	Luo et al.
49	Jianguo in Fuxin	basalt	K-Ar	92.12±2.08	Wang et al.
50	Sihetun	basalt	K-Ar	124.16-133.59	Zhu et al.
51	Zhuangchengzi	andesite	K-Ar	120.42-122.31	Zhu et al.
52	Zhuanchengzi in Yixian	andesite	K-Ar	122.31-120.42	Zhu et al
53	Jianguo in Fuxin	basalt	Ar-Ar	105.5±0.5	Zhu et al
54	Jianguo in Fuxin	andesite	Ar-Ar	100.4±1.6	Zhu et al
55	Songjia	andesite	Rb-Sr	140±6	Zhu et al.
56	Yiwulvshan	miliolite	Ar-Ar	219±4	Zhang et al.
57	Yiwulvshan	miliolite	Ar-Ar	116±2	Zhang et al.
58	Yiwulvshan	miliolite	Ar-Ar	127±3	Zhang et al.
59	Sihetun	olivine basalt	Ar-Ar	132.9±1.5	Peng et al.
60	Huangbanjigou	liparitic tuff	Ar-Ar	127.4±1.3	Peng et al.
61	Sihetun	ellipsoidal lava	Ar-Ar	126.1±1.7	Peng et al.
62	Sihetun	olivine basalt	K-Ar	133.3±2.6	Peng et al.
63	Sihetun	olivine basalt	K-Ar	133.6±2.6	Peng et al.
64	Sihetun	olivine basalt	K-Ar	124.16±2.4	Peng et al.
65	Sihetun	olivine basalt	K-Ar	124.42±2.4	Peng et al.
66	Sihetun	olivine basalt	K-Ar	124.91±2.4	Peng et al.
67	Houyanzigou	olivine basalt	Ar-Ar	130.6±0.5	Peng et al.
68	Sihetun	olivine basalt	Ar-Ar	127.7±0.2	Peng et al.
69	Jianguo	basalt	K-Ar	107.3 ± 1.6	Zhang et al.
70	Jianguo	ring tephrite	K-Ar	94.2 ± 1.4	Zhang et al.
71	Jianguo	basalt	K-Ar	97.1±1.4	Zheng et al.
72	Jianguo	basalt	K-Ar	98.0±1.4	Zheng et al.
73	Zaocishan	dacite porphyry	Ar-Ar	122.09±0.29	Wang et al.

(*Continued*)

Table 1. Rock samples and dating results of volcanic in Fuxin and Heishan-Zhangwu area

NO	Sample Location	Lithology	Test method	Age/Ma	Data source
74	Zaocishan	dacite porphyry	Ar-Ar	122.36	Wang et al.
75	Zaocishan	dacite porphyry	Ar-Ar	121.80±1.36	Wang et al.
76	Sihetun	basalt	U-Pb	112±3	Ji et al.
77	Zhuanchengzi in Yixian	basalt	U-Pb	120±2	Ji et al.
78	Jingangshan in Yixian	dacite porphyry	U-Pb	126±0.5	Ji et al.
79	Zhuanchengzi in Yixian	andesite	U-Pb	132±1	Ji et al.
80	Sihetun	tuff	U-Pb	124.4±1.6	Yang et al.
81	Huangbanjigou	tuff	U-Pb	123.1±2.1	Yang et al.
82	Huangbanjigou	tuff	U-Pb	122.1±1.4	Yang et al.
83	Jianguo	basalttrachyandensite	Ar-Ar	116.8±3.0	Zhu et al.
84	Fanjiagou in Yixian	rhyolite	U-Pb	118.9±1.4	Zhang et al.
85	Fanjiagou in Yixian	rhyolite	U-Pb	119.8±1.9	Zhang et al.
86	Huanghuashan breccia	dacite porphyry	Ar-Ar	122.1±0.3	Zhang et al.
87	Huanghuashan breccia	dacite porphyry	Ar-Ar	121.8±1.4	Zhang et al.
88	Sihetun	basaltic andesite	Ar-Ar	126.1±0.4	Zhang et al.
89	Sihetun	basalt	K-Ar	124.2±2.4	Li et al.
90	Sihetun	basalt	K-Ar	124.4±2.4	Li et al.
91	Sihetun	basalt	K-Ar	125.0±2.4	Li et al.
92	Sihetun	basalt	K-Ar	124.6±2.5	Li et al.
93	Sihetun	basalt	K-Ar	124.8±2.3	Li et al.
94	Sihetun	basalt	K-Ar	125.1±2.4	Li et al.
95	Sihetun	basalt	K-Ar	124.9±2.4	Li et al.
96	Sihetun	basalt	K-Ar	126.1±2.6	Li et al.
97	Sihetun	basalt	K-Ar	129.3±2.5	Li et al.
98	Sihetun	basalt	K-Ar	129.2±2.6	Li et al.
99	Sihetun	basalt	K-Ar	133.3±2.6	Li et al.
100	Sihetun	basalt	K-Ar	133.6±2.6	Li et al.
101	Sihetun	basalt	K-Ar	133.1±2.6	Li et al.
102	Maozishan in Lingyuan	tuff	U-Pb	125.4±0.9	Zhang et al.
103	Maozishan in Lingyuan	rhyolite	U-Pb	125.3±0.9	Zhang et al.
104	Maozishan in Lingyuan	rhyolite	U-Pb	124.4±1.1	Zhang et al.
105	Guojiagou in Lingyuan	tuff	U-Pb	122.3±2.1	Zhang et al.
106	Dawangzhangzi in Lingyuan	rhyolite	U-Pb	123±1.7	Zhang et al.
107	Zhangwu	andesite	U-Pb	126±2	Huang et al.
108	Lihenggou in Yixian	rhyolite	Ar-Ar	113.2±1.6	Shao et al.
109	Daxingzhuang in Linghai	amphibole andesite	U-Pb	114.9±2.5	Shao et al.
110	Dasijiazi in Zhangwu	rhyolite	U-Pb	122.4 ±0.4 Ma	Xiao et al.

(*Continued*)

Table 1. Rock samples and dating results of volcanic in Fuxin and Heishan-Zhangwu area

NO	Sample Location	Lithology	Test method	Age/Ma	Data source
111	Kazuo butte	andesite	K-Ar	125.7 ±4.3	Wang et al.
112	Kazuo butte	andesite	U-Pb	126.0±1.5	Wang et al.
113	Lingyuan	rhyolite	U-Pb	124.4±1.4	Meng et al.
114	Badaohao in Heishan	trachyandensite	U-Pb	125.7±1.7	This Paper
115	Zhangluotun in Heishan	rhyolite	U-Pb	124.9±2.9	This Paper
116	Yaocangtu in Heishan	coloradoite	U-Pb	115.5±1.5	This Paper
117	Nalishan in Yaocangtu	basalt	U-Pb	56±2.9	This Paper
118	Liangshan in Heishan	trachyandensite	U-Pb	129.7±1.6	This Paper
119	Beizhuanchengzi	andesite	U-Pb	132.3±2.3	This Paper
120	Huanghuashan in Yixian	dacite	U-Pb	126.3±1.7	This Paper
121	Juliangtun in Yixian	trachyandensite	U-Pb	125.8±1.9	This Paper
122	Lijiatai	andesite	U-Pb	127.0±5.1	This Paper
123	Xinglonggou in Yixian	andesite	U-Pb	122.3±4.5	This Paper
124	Songbahu in Yixian	andesite	U-Pb	129.0±2.4	This Paper

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