



SHRIMP Zircon U-Pb Dating on the Early Cretaceous Volcanics in Zhangwu-Heishan Area, West Liaoning Province, China and its Geological Significance

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ABSTRACT

Due to special structural location and the output of precious fossils, west Liaoning Province has become a hot subject of research. The horizon and age of volcanic rock play an important role in understanding biostratigraphy, structural and sedimentary evolution of west Liaoning Province and local coal exploration. During this work, over 20 volcanic rock samples were collected from Fuxin-Yixian Basin and Zhangwu-Heishan Area, and 11 samples were performed SHRIMP U-Pb isotope analysis. Combining the new data obtained with the age of Mesozoic volcanic rock in west Liaoning Province, Cretaceous volcanic activities in west Liaoning Province can be divided into 5 stages, namely $132\pm 1\text{Ma}$, $126\pm 1\text{Ma}$, $122\pm 2\text{Ma}$, $115\pm 2\text{Ma}$ and $100\pm 5\text{Ma}$. In reference to field observation, the volcanic rock in Zhangwu-Heishan Area includes 3 suites of early Cretaceous volcanic rock and 1 suite of Paleogene olivine-enclave-bearing basalt. Overlying Jiufotang Formation is a volcanic rock series, which occurs at Jianguo of Fuxin, Yaocangtu of Heishan County, Baizitun in the east of Faku County and more, is temporarily named as Gangtaishan Formation or is incorporated into Jiufotang Formation. Igneous rock series of Dalinghe Formation (Daxingzhuang Formation) overlying Sunjiawan Formation of early Cretaceous System wasn't found in Fuxin-Yixian Basin and Zhangwu-Heishan Area, so it is proposed that this formation is absent in the study area. The stratigraphic succession of Zhangwu-Heishan Area was clarified and the conclusion that no Cretaceous coal seam can be found below volcanic rock in Zhangwu-Heishan Area was drawn. The inherited zircon of Archean Eon was found in volcanic rock samples from Yixian Formation of early Cretaceous System.

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

Datación U-Pb SHRIMP de rocas volcánicas del Cretácico inferior en el área de Zhangwu-Heishan, al occidente de la provincia china de Liaoning y su importancia geológica

RESUMEN

Debido a su ubicación estructural especial y el desarrollo de fósiles valiosos, el occidente de la provincia china de Liaoning se ha convertido en un centro de interés para la investigación. El horizonte y la edad de las rocas volcánicas juegan un papel importante en el conocimiento de la bioestratigrafía y la evolución estructural y sedimentaria del occidente de la provincia y de la exploración local de carbón. Durante este trabajo más de veinte muestra de rocas volcánicas recolectadas en la cuenca de Fuxin-Yixian y en el área de Zhangwu-Heishan, y a once de estas muestras se les realizaron análisis de datación isotópica SHRIMP U-Pb (Datación U-Pb a través de la Microsonda de Iones de Alta-Resolución). Al combinar la nueva información obtenida con la edad de las rocas volcánicas del Mesozoico en el occidente de la provincia de Liaoning, las actividades volcánicas del cretácico pueden dividirse en cinco etapas: $132\pm 1\text{Ma}$, $126\pm 1\text{Ma}$, $122\pm 2\text{Ma}$, $115\pm 2\text{Ma}$ y $100\pm 5\text{Ma}$. En cuanto a la observación de campo, las rocas volcánicas del área de Zhangwu-Heishan incluyen tres patrones de rocas volcánicas del Cretácico inferior y un patrón de basalto paleógeno con enclave de olivino. Una serie de rocas volcánicas cubre la formación Jiufotang, las cuales se encuentran en Jianguo de Fuxin, condado Yaocangtu de Heishan, y Bazitun, en el oriente del condado Faku, y se denomina temporalmente formación Gangtaishan o se incorpora a la formación Jiufotang. Las series de rocas ígneas de la formación Dalinghe (formación Daxingzhuang) que se superponen a la formación Sunjiawan del sistema cretácico inferior no fueron encontradas en la cuenca de Fuxin-Yixian ni en el área Zhangwu-Heishan, por lo que se propone que esta formación es ausente en el área de estudio. La sucesión estratigráfica del área de Zhangwu-Heishan fue clarificada y surgió la conclusión de que una veta de carbón del Cretácico podría ser hallada bajo sus rocas volcánicas. El círculo heredado del Eón Arcaico se encontró en muestras de roca volcánica de la formación Yixian, del sistema cretácico temprano.

Palabras clave: occidente de la provincia Liaoning; área de Zhangwu-Heishan; rocas volcánicas del Mesozoico; datación isotópica SHRIMP U-Pb; significación geológica.

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1. Geologic Setting

Zhangwu-Heishan area is located to the east of Fuxin-Yixian basin. Besides the Quaternary soil, the study area is mostly covered with volcanic rock, which is dominated by the intermediate-basic andesite, trachyandesite and basaltic andesite, with a minority taken by the dacite, rhyolite etc. (Figure 1). In the research history, various workers have proposed different nomenclatures, evolutionary processes, and chronostratigraphy for those igneous rocks. It is thus important and necessary to unify those discrepancies, which have brought considerable inconveniences and potential issues for regional correlation, biostratigraphic studies and resources exploration. And this is the main effort this paper aiming to contribute. Field investigation starts with Yixian Basin which has been densely studied by various investigators, and gradually advances to the north and northeast parts of Fuxin-Yixian Basin. Key volcanic outcrops are highlighted and recorded; meanwhile, igneous samples are collected from outcrops or rock cores in different horizons for SHRIMP U-Pb isotopic dating. Combining with data from previous researches, the age and main eruption periods of the above volcanic rock will be generally delineated, and the sequence relationships between volcanic rock and main coal-bearing strata will be identified to provide possible assistances for future geological researches.

In the middle and late Jurassic Period, due to southward movement of Siberian Plate and westward subduction of Pacific Plate, west Liaoning Province was extruded in the direction of NW-SE and mainly features NE-

and NNE-trending structures (Wang, 2001; Ren, 2002). Adjacent to Inner Mongolia-Xing'an Orogenic Belt and Songliao Basin, West Liaoning Province is bordered by Chifeng-Kaiyuan Fracture to the north, connected to EW-trending Yanshan Orogenic Belt to the west, and separated from Liaodong Uplift Zone by Yilan-Yitong Fracture Zone to the east. Its tectonic position belongs to transition zone of North China Block, Liaodong Uplift Zone and Inner Mongolia-Xing'an Orogenic Belt (Chen et al., 1997).

The study area is mainly characterized by NE- and NNE-trending faulted structures. Although nappe structures, extensional structures and strike-slip structures are developed in this area, extensional activities dominated during Yixianian. The major axis of Mesozoic sedimentary basin in this area is mainly NNE-trending. With abundant volcanic rock developed during Yixianian, temporal basin was obviously controlled by basin-margin extensional fractures, which are mainly characterized by NNE-trending fractures. During Jiufoctangian Period, graben faulting in west Liaoning Province was further developed; the volcanism calmed though, with tuffaceous materials comprise the majority of this formation. Subsequently, a relatively small-scaled intermediate-basic volcanic eruption occurred and the basin gradually received the sediment from Shahai Formation and Fuxin Formation of early Cretaceous Epoch and Sunjiawan Formation of late Cretaceous Epoch. The transition of Mesozoic structures in west Liaoning Province shows very good spatiotemporal coupling between mantle process and lithosphere thinning in deep part.

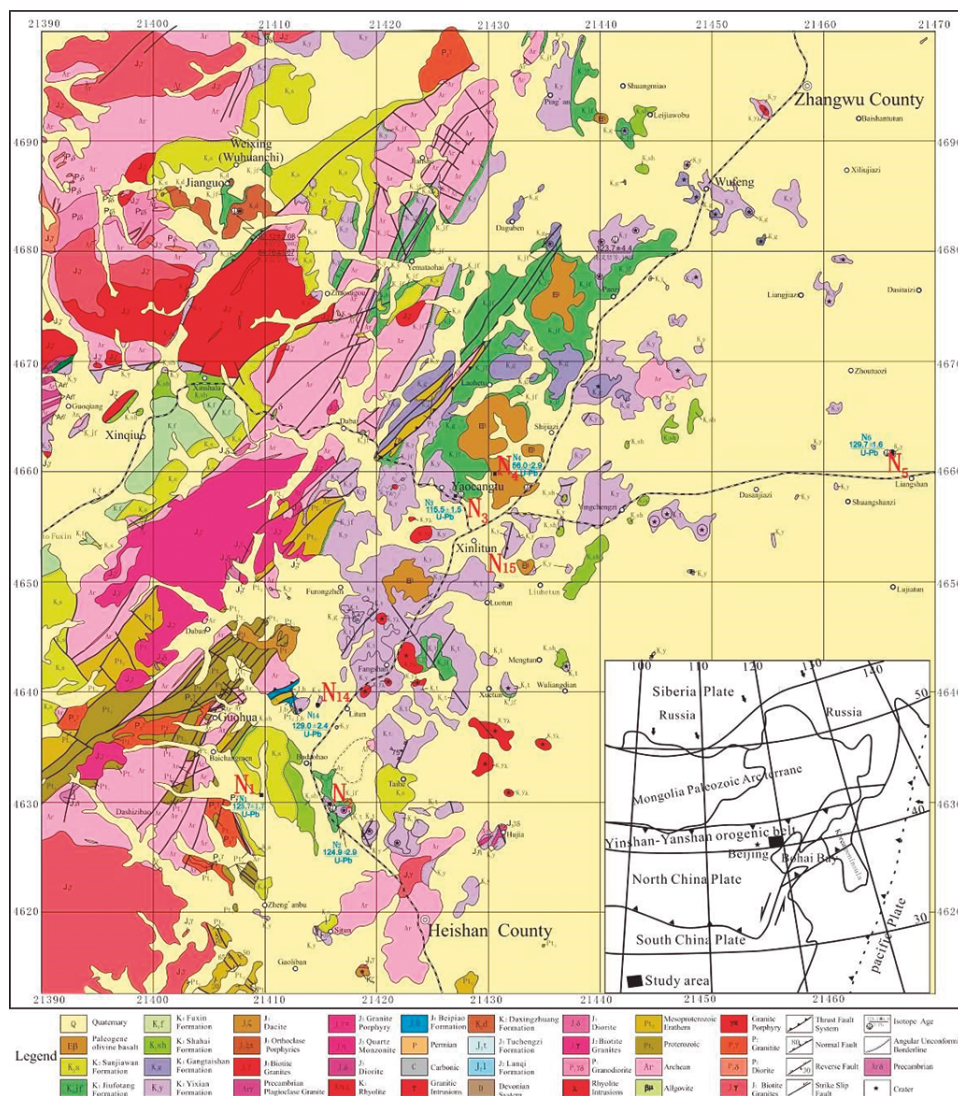


Figure 1. Geologic Map of Zhangwu-Heishan Area and Sampling Location

2. Sampling and Test

The reported data on the absolute age of volcanic rock in this area are mainly derived from K-Ar or Ar-Ar method. During this research, 11 volcanic rock samples are collected and analyzed with higher-precision SHRIMP U-Pb isotopic dating method. Specific sample ID, sampling location, lithology determined through slice identification and more are shown in Figure 1 and Table 1. It should be noted that results of the same sample are subject to different testing methods. Therefore, during this work, 6 samples are collected from Yixian Basin so as to accurately correlate the age of volcanic rock in Zhangwu-Heishan Area with that in Fuxin-Yixian Basin and provide compelling evidence. Test samples used by SHRIMP dating method are the zircon selected from volcanic rock samples. During the testing, outer margin should be distinguished from the core, because the outer margin of zircon is younger than the core. If the test result is derived from chip zircon samples, it may be not the outer margin, result in that the value of absolute age is relatively higher, and can't reflect the accurate age of volcanic rock. Sample N1 is from the bottom of Borehole BS13 in Badaohao exploration area, Heishan County (Cai et al., 2008 & 2009). Zhangluotun sample (N2) is of quartz trachyandesite, is distributed on the southeast side of Badaohao, obviously intrudes into the tuffite and tuffaceous clastic rock, generally inclines to the inside of volcanic conduit and has large obliquity, and fluidal structures are developed inside the trachyandesite and are almost erective at volcanic conduit (Plate I-7). Liangshan trachyandesite (N3) lies in the northwest of Liangshan Township, takes the form of independent small hill due to weathering and is covered with Quaternary System; lava flow unconformably covers the sedimentary rock in a small hill to the north of Shuangshanzi; and 30-40cm-thick baked layer lies on its top. The trachyandesite is greenish black and has compact and even structure; fluidal structures and columnar jointing are developed, the former of which has almost erective occurrence; and the samples are collected from volcanic conduit (Plate I-1). Sample N4 is collected from Nalishan of Yaocangtu. Sample N5 is from Dongliangshan of Heishan County. The samples for isotopic dating of Fuxin-Yixian Basin are collected from Beizhuanchengzi in the southwest of Qinghem, Huanghuashan in the southeast of Yi County, Lijiatai in the southeast of Juliangtun of Yi County (Figures 3-4), Xinglonggou in the southeast of Yi County (Figures 3-4), Songbahu in the southeast of Yi County, Tonglvou, and Luotaishan in the north of Badaohao. Sampling locations are detailed as Figure 1.

Experimental procedures are as follows: crush and screen volcanic rock samples, select automorphic zircon crystals which aren't ground and have no inclusion, and it should be clean and transparent under binocular eyepiece; then combine several selected zircon samples together to make them into resin target; polish the target; and perform the photomicrograph of reflected light, transmitted light and cathode luminescence. Cathode luminescence is performed in Chinese Academy of Geological Sciences and U-Pb isotope analysis is conducted with SHRIMP-II-type ionic probe in SHRIMP Center of the Institute of Geology of Chinese Academy of Geological Sciences. During the analysis, standard zircon TEM (417Ma) is used for fractionation correction between elements. For detailed SHRIMP analysis method and process, please refer to Williams (1987). The data are processed with Ludwig SQUID1.0 program and ISOPLOT program (1999 & 2001), and decay constant is the value recommended by Steiger et al. (1997). Common lead correction is implemented through directly determining ^{204}Pb . The dating data used by this paper are the average of 5 values measured at the same survey point and have the error of 1σ . $^{206}\text{Pb}/^{238}\text{U}$ age is used for all samples and the weighted average has the confidence level of 95%.

3. Result and Discussion of Isotopic Dating

Result of Isotopic Dating

During this work, totally 20 volcanic rock samples are collected from Fuxin-Yixian Basin and Zhangwu-Heishan Area, 15 of which are sent to the laboratory for testing. SHRIMP method was performed for 11 samples, within which only 1 sample indicates a Paleogene eruptive origin, the rest 10 samples are all from eruptive rock in the medium term of early Cretaceous Period. Sampling locations are shown in figure 2. Part of zircon is relatively old and the zircon tested may be ancient zircon taken up during magmatic eruption.

The breccia in Huanghuashan is the uppermost lithological segment (Ren et al., 1997; Zhang et al., 2004) of Yixian Formation and its age is in line with the top boundary of Yixian Formation. During this work, the age determined is $126.3 \pm 1.7\text{Ma}$, which is possible over-estimated the real age since the zircon tested is mainly from volcanic rubble in the samples, and can't represent the accurate age of this horizon. The ID and sampling location of selected zircon, concordia curve of corresponding age, and statistic histogram are shown as Figure 2.

Discussion

1) Age and Sequence of Volcanic Rock in Zhangwu-Heishan Area

During field work, volcanic sequence and eruption period are investigated and it is deemed that 3 suites of Cretaceous volcanic rock in Zhangwu-Heishan Area can be distinguished. The first set of volcanic rock lies in the lowest horizon, is of intermediate-basic basaltic andesite, features a large amount of vesicular amygdaloidal structure, is the result of fissure eruption, and was formed during tectonic activities. The second set lies in the middle horizon, is of intermediate trachyandesite, features trachyandesite and bentonite deposit produced by the alteration, and was formed during tectonic stabilization period. The third set lies in the highest horizon, is of compact intermediate-basic basaltic andesite, is the result of fissure eruption, is mainly characterized by hypabyssal andesite and unconformably overlies the bentonite or other older strata, and lava flow produced about 30cm-thick baked layer in underlying strata (Plate I-6). The third set of volcanic rock should be Gangtaishan Formation in Xinlun named by Tan in 1926, is contemporaneous with Yushugou Formation to the west of Yi County, and is also known as Daxingzhuang Formation in 1:200,000 geologic map by Regional Survey Team of Liaoning Province and Zhanglaogongtun Formation denominated by Wang (2004).

From the aspect of lithology and eruptive sequence, correlated with contemporaneous volcanic rock in Yi County, the first set of basaltic andesite is equivalent to the second set of basaltic andesite in Yixian Formation; the second set of intermediate trachyandesite and bentonite are comparable with the breccia in Huanghuashan and should be included in Huanghuashan Formation; and the third set of intermediate-basic basaltic andesite overlies the trachyandesite, underlies Badaohao Formation, should belong to volcanic rock in the medium term of early Cretaceous Period, and is corresponding to Gangtaishan Formation or Yushugou Formation, Daxingzhuang Formation and Zhanglaogongtun Formation.

The outcrops of the first set of early Cretaceous volcanic rock include: basaltic andesite in Shijiazzi Township to the northeast of Xinlun (Plate I-4) features a large amount of vesicular and amygdaloidal structures and is abundant in agate. The hypabyssal andesite in Luotaishan overlies the outcrop of coal-bearing series of Beipiao Formation of early Jurassic Epoch and is the lowest intermediate volcanic rock of early Cretaceous Epoch. This set of volcanic rock is named as Daxingzhuang Formation in 1:200,000 geologic map, which may be wrong, has the age of $129.0 \pm 2.4\text{Ma}$ determined by SHRIMP method, and should be included in Yixian Formation. The hypabyssal andesite in Shuangshanzi of Liangshan is distributed in Shuangshanzi in the southwest of Liangshan Township in the west of Xinmin County, takes the form of independent small hill due to weathering and is covered with Quaternary System; lava flow unconformably covers the sedimentary rock in a small hill; and 30-40cm thick baked layer lies on its top. The andesite is dark gray and has compact and even structure; fluidal structures and columnar jointing are developed (Plate I-1), the former of which has almost erective occurrence; and the samples are collected from volcanic conduit. This set of volcanic rock is also denominated as Daxingzhuang Formation in 1:200,000 geologic map, has isotopic age of $129.5 \pm 1.6\text{Ma}$ and $129.7 \pm 1.6\text{Ma}$ determined with SHRIMP method, belongs to older volcanic rock and can be correlated with Yixian Formation in Yi County. The hypabyssal andesite in Zhangluotun to the southeast of Badaohao Coal Mine obviously intrudes into the tuffite and tuffaceous clastic rock, generally inclines to the inside of volcanic conduit and has the obliquity of 40° - 50° , and fluidal structures are developed inside the trachyandesite and are almost erective at volcanic conduit. This set of andesite which was originally denominated as Yushugou Formation or Daxingzhuang Formation has the isotopic age of $124.9 \pm 2.9\text{Ma}$ and $122.2 \pm 4.1\text{Ma}$ determined with SHRIMP method, belongs to older volcanic rock and can be correlated with Yixian Formation (Plate I-7).

Table 1. Summary of SHRIMP U-Pb Isotopic Testing Result of Volcanic Rock in Fuxin and Its Peripheral Areas

Sample ID	Sampling Location	Color	Lithology by Slice Identification	Age (Ma)	Volcanic Eruption Period	Horizon in 1:200,000 Geologic Map (1972)	Original Horizon in 1:50,000 Geologic Map by the 107 th Brigade	Horizon Currently Determined
N1	1160m in Borehole BS-13 at Badaohao	Grayish Green	Trachyandesite	125.7±1.7	②-③	J ₃ t Tuhulu Formation		K ₁ y Yixian Formation
N2	Zhangluotun to the Southeast of Badaohao	Purplish Grey	Rhyolite	124.9±2.9	②-③	J ₃ t Tuhulu Formation		K ₁ t Tuhulu Formation
N3	To the East of Yaocangtu in Heishan County	Grey Black	Quartz Trachyandesite	115.5±1.5	④	J ₃ t Tuhulu Formation	Yixian Formation	K _{1g} Gangtaishan Formation
N4	Nalishan in Yaocangtu	Grey Black	Basalt	56±2.9		Covered with Quaternary	Covered with Quaternary	E Paleogene System
N5	Dongliangshan in Heishan County	Grey Black	Trachyandesite	129.7±1.6	②	J ₃ t Tuhulu Formation	Daxingzhuang Formation	K ₁ y Yixian Formation
N6	Beizhuanchengzi in the Southwest of Qinghemen	Grey	Andesite	132.3±2.3	①	J ₃ t Tuhulu Formation	Yixian Formation	K ₁ y Yixian Formation
N8	Huanghuashan in the Southeast of Yi County	Grayish Yellow	Dacite	126.3±1.7	②	J ₃ t Tuhulu Formation	Yixian Formation	K ₁ t Tuhulu Formation
N11	Lijiatai in the southeast of Yi County	Claret	Trachyandesite	125.8±1.9	②	J ₃ y Yixian Formation	Dalinghe Formation	K ₁ t Tuhulu Formation
N12	Xinglonggou in the Southeast of Yi County	Claret	Andesite	127.0±5.1	②	J ₃ y Yixian Formation	Daxingzhuang Formation	K ₁ t Tuhulu Formation
N13	Tonglvigou of Songbahu in the Southeast of Yi County	Caesious	Andesite	122.3±4.5	③	J ₃ t Tuhulu Formation	Yixian Formation	K ₁ t Tuhulu Formation
N14	Luotaishan in the North of Badaohao	Offwhite	Andesite	129.0±2.4	①-②	J ₃ t Tuhulu Formation	Yixian Formation	K ₁ y Yixian Formation

The second set of early Cretaceous volcanic rock features the trachyandesite and bentonite, and bentonite deposits are found in Hala and Shaojianshanzi in the southwest of Zhangwu County, Xiashitu of Yaocangtu in the northwest of Xinlun and Douyawopu in the southeast of Zhangwu County. Bentonite deposits are mainly composed of montmorillonite minerals, which can account for over 80% and are of volcanic genesis and sedimentary genesis. Sedimentogenic bentonite is the result of hydrolysis, diagenesis, weathering or low-temperature hydrothermal alteration of intermediate-basic volcanic rock, especially trachyandesitic pyroclast or volcanic ash falling into lake basin, should be contemporaneous with andesitic volcanic eruption in Huanghuashan, and can represent the product of the second set of volcanic eruption in this area. The outcrops include: 1) Bentonite deposits in Hala and Shaojianshanzi areas are located in the southeast of Zhangwu County and

between Paozi and Daguben, are covered with the andesite later eroded, and overlie clastic rock (Plate I-5 and Figure 4-2). The bentonite is closely related to the trachyandesite in Huanghuashan in terms of composition and genesis, and shows the interruption in deposition with the overlying basalt andesite, which should be Gangtaishan Formation (Figure 4-1), Yushugou Formation or Daxingzhuang Formation. 2) The bentonite in Yaocangtu is distributed in Xiashitu of Yaocangtu in the northwest of Xinlun (Plate I-8), is covered with the hypabyssal andesite later erupted, and shows the interruption in deposition between them. Bentonite layer overlies a set of clastic rock, which becomes finer and finer bottom-up and is the result of retrogradation during the expansion of lake basin. The importance should be attached to the discovery of precious fossils in sedimentary deposit below this set of volcanic rock.

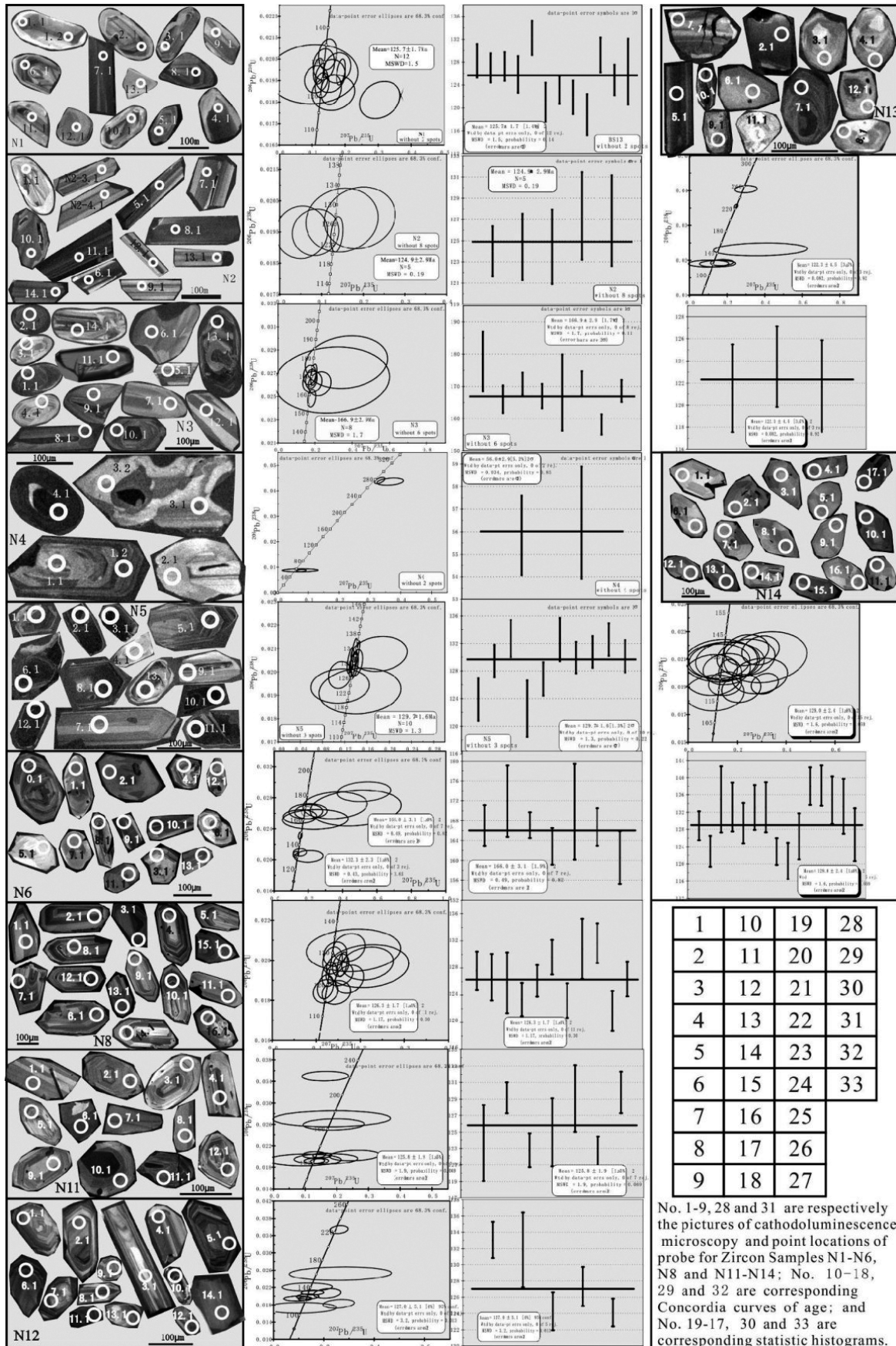


Figure 2. ID and Sampling Locations of Selected Zircon, Concordia Curve of Age and Statistic Histogram

4) Sequence Relationship between Volcanic Rock and Coal-bearing Strata in Zhangwu-Heishan Area

It is previously thought that the so-called Dalinghe volcanic rock which is distributed along Dalinghe Fracture overlay red bed of Sunjiawan Formation and belonged to upper Cretaceous Series, so someone suggested searching the coal below the volcanic rock. The investigation on Lijiadian-Baimiaozi to the southeast of Juliangtun shows that the above volcanic rock has the faulted contact relationship with red bed and doesn't overlie the red bed, that the red bed originally defined doesn't belong to Sunjiawan Formation and is the conglomerate at the bottom of Shahai Formation, and that andesitic volcanic rock of so-called Dalinghe Formation has the age of 125.8 ± 1.9 Ma (N11) and 127.0 ± 5.1 Ma (N12) according to SHRIMP method and should belongs to Yixian Formation. During the field reconnaissance in the study area, the expected Dalinghe Formation isn't found, so it is thought that there is no volcanic rock of Dalinghe Formation. Early Cretaceous volcanic rock in Zhangwu-Heishan study area, despite of Yixian Formation of the first cycle, Gangtaishan Formation of the second cycle, or contemporaneous volcanic rock with different names (such as Daxingzhuang Formation, Yushugou Formation, Zhanglaogongtun Formation and more), has older and lower horizon than Shahai Formation (Badaohao Formation), and Jiufotang Formation which underlies Gangtaishan Formation is of crater-lake deposit after volcanic eruption, is distributed in a limited area and is less wide-spread than fault-trough lake basin genetic Shahai Formation and Fuxin Formation after intermediate-basic volcanic eruption. Jiufotang Formation barely shows the sign of coal accumulation, so it is impossible to find the coal of Shahai Formation or Fuxin Formation below the volcanic rock.

4. Conclusions

Based on the research of volcanic rock in Fuxin Basin and its peripheral areas, the following conclusions could be drawn:

1. Based on the age of Mesozoic volcanic rock obtained from SHRIMP U-Pb isotope analysis of 11 volcanic rocks in west Liaoning Province in this study, Cretaceous volcanic activities in the research area can be divided into 5 stages, namely 132 ± 1 Ma, 126 ± 1 Ma, 122 ± 2 Ma, 115 ± 2 Ma and 100 ± 5 Ma.
2. There are 2 sets of early Cretaceous volcanic rock and 1 set of Paleogene volcanic rock in Fuxin Basin and Zhangwu-Heishan area: early Cretaceous volcanic rock is thick and widespread, has various lithologies and complicated denominations, while Paleogene basic basalt is mainly located at Nalishan to the southeast of Yemataohai. Early Cretaceous volcanic rock in the studying area can be divided into 2 cycles. The first cycle starts with basic basalt, is represented by narrow-sensed Yixian Formation and ends with intermediate trachyandesite and crater-lake deposit, namely Huanghuashan breccia and Jiufotang Formation. Several lacustrine sediments were deposited during volcanic dormant period lying between basic and intermediate volcanic rock. Basic basalt, with the isotopic age of about 106 Ma-108 Ma, represents the second cycle; it unconformably underlain volcanic rock or sedimentary rock and has baked the strata beneath it. This sequence is featured by alkaline basalt in the upper section of Jianguo, Wuhuanchi Township, and is mainly distributed in Douyawopu and Yaocangtu in Zhangwu County.
3. The expected Dalinghe Formation is absent in west Liaoning Province, and thus leads to the postulation that the Dalinghe Formation doesn't exist in the study area and should be canceled. Early Cretaceous volcanic rock in Zhangwu-Heishan study area, despite of Yixian Formation of the first cycle, Gangtaishan Formation of the second cycle, or contemporaneous volcanic rock with different names (such as Daxingzhuang Formation, Yushugou Formation, Zhanglaogongtun Formation and more), is older and has lower horizon than Badaohao Formation and the contemporaneous Shahai Formation, so it is impossible to find the coal of Badaohao Formation, Shahai Formation or Fuxin Formation below the volcanic rock.

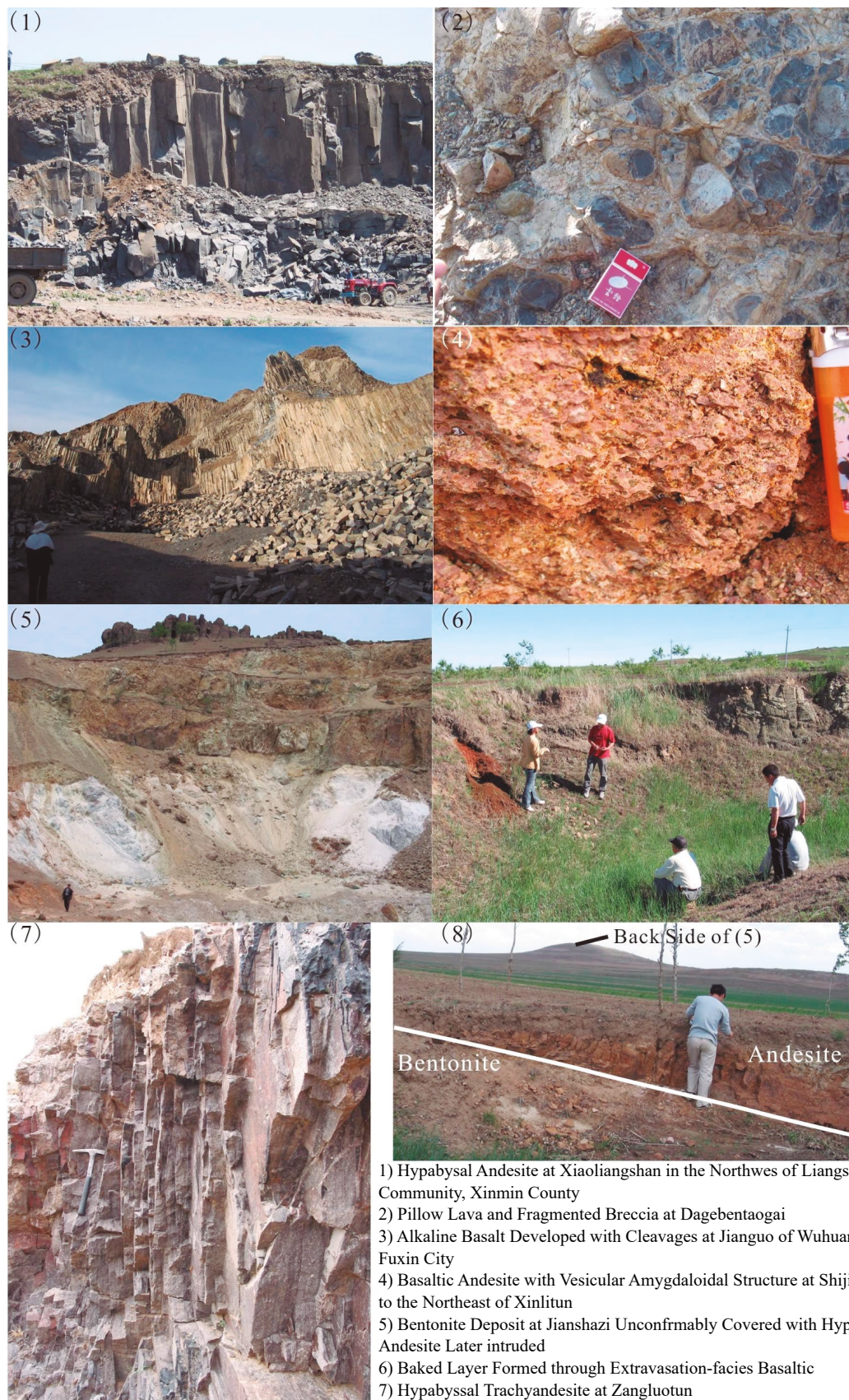
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Appendix 1:

Plate I



- 1) Hypabyssal Andesite at Xiaoliangshan in the Northwest of Liangshan Community, Xinmin County
- 2) Pillow Lava and Fragmented Breccia at Dagebentaogai
- 3) Alkaline Basalt Developed with Cleavages at Jianguo of Wuhuan Township, Fuxin City
- 4) Basaltic Andesite with Vesicular Amygdaloidal Structure at Shijiazhi Township to the Northeast of Xinlitun
- 5) Bentonite Deposit at Jianshazi Unconformably Covered with Hypabyssal Andesite Later Intruded
- 6) Baked Layer Formed through Extrusion-facies Basaltic
- 7) Hypabyssal Trachyandesite at Zanglutun
- 8) Andesite at Xiashitou of Cangtu County Overlying the Bentonite

Plate 1