Journal of Groundwater Science and Engineering
ISSN 2305-7068
Indexed by ESCI CABI CSA
Scopus GeoRef AJ CNKI

Features and values of geological heritage resources in Shunping County, Hebei Province

YANG Jin-song, LIU Zhe, WANG Xiang-dong, ZHAO Hua, SONG lei, LIU Tai-bei, WANG Cheng-min, ZHANG Peng

Citation:
YANG Jin-song, LIU Zhe, WANG Xiang-dong, ZHAO Hua, SONG lei, LIU Tai-bei, WANG Cheng-min, ZHANG Peng. Features and values of geological heritage resources in Shunping County, Hebei Province[J]. *Journal of Groundwater Science and Engineering*, 2020, 8(4): 349-357.

View online: https://doi.org/10.19637/j.cnki.2305-7068.2020.04.005

DOI: 10.19637/j.cnki.2305–7068.2020.04.005

Features and values of geological heritage resources in Shunping County, Hebei Province

YANG Jin-song[1,2,3], LIU Zhe[1,2*], WANG Xiang-dong[4], ZHAO Hua[1,2], SONG lei[1,2], LIU Tai-bei[1,2], WANG Cheng-min[1,2], ZHANG Peng[1,2]

[1] Institute of Hydrogeology and Environmental Geology, Chinese Academy of Geological Sciences, Shijiazhuang 050061, China.
[2] Key Laboratory of Quaternary Chronology and Hydro-Environmental Evolution, China Geological Survey, Shijiazhuang 050061, China.
[3] Institute of Geology, China Earthquake Administration, Beijing 100037, China.
[4] Qiqihar University, Qiqihar, Heilongjiang Province 161006, China.

Abstract: Hebei Province is rich in geological heritage resources due to its diverse landforms and unique natural conditions. However, detailed investigation and study of the resources are still limited, and a systematic survey conducted on a small scale has not been fully implemented. In this paper, the resource types and characteristics of the geological heritage in Shunping County are systematically discussed, on the basis of field investigation and scientific evaluation. With reference to the existing criteria for geological heritage resources survey, the heritage values and corresponding levels were assessed by using multi-factor quantitative evaluation approach. The results show that there are 33 geological heritage sites in Shunping County, which fall into 3 categories, 10 classes and 17 subcategories. Among them, 2 heritage sites are above the provincial level, 14 heritage sites are at the provincial level and 17 ones are below the level. These heritage sites are not only natural resources with great tourism potential, but also valuable asset in geological research, human history, ecological conservation, scientific education and some other aspects. It is hence of great significance to conduct the scientific and reasonable appraisal for having a better understanding, good protection and development of the geological heritage resources in Hebei Province.

Keywords: Geological heritage; Landscape assessment; Hebei Province; Shunping County; Taihang Mountain

Received: 11 Aug 2020/ Accepted: 16 Oct 2020

Introduction

A geological heritage, formed by various internal and external geological processes and developed in the long geological history, constitutes one of precious and non-renewable natural resources (Ministry of Land and Resources, 2017). In order to have a better understanding of the resources prospect, a nationwide survey of geological heritage sites in China has been completed via a project hosted by China Geological Survey (DONG Ying and CAO Xiao-juan, 2019). However, detailed and small-scale investigations to the resources were only conducted in some national geological parks (ZHANG Huan-xin *et al.* 2018) and limited scenic areas with economic significance (FU Yin-hong, 2020). In line with the national strategies of "ecological civilization" and "rural revitalization", as well as the development of geological tourism, detailed geological heritage investigations are urgently needed (ZHONG Zi-ran, 2018; DING Hua *et al.* 2020).

Due to its diverse landforms and unique natural conditions, there are many geological relics in Hebei Province (NIU Ping-shan *et al.* 2004; XIAO Gui-zhen *et al*. 2007; ZHANG Zhao-yi *et*

*Corresponding author. E-mail: liuzhe1130@163.com

al. 2018; CHEN Bin *et al.* 2019). However, the value of the resources which have great potential for exploitation around Yan Mountain, Taihang Mountain and the coastline is yet unknown (LI Yan-chen, 2018). In this paper, basic geological background and various values of the geological heritage resources in Shunping County are elaborated and presented, which would set up a representative example for detailed geological heritage investigation and assessment in a county scale.

1 Geological background of Shunping County

Shunping County, located in the center of the economic circle of Beijing, Tianjin, Shijiazhuang, Baoding and Taiyuan, has great advantage of geographical location. On geomorphologic aspects, it is located at the intersection zone of Taihang Mountain and North China Plain, with the Taihang Mountain in the northwest and the North China Plain in the southeast. Because of the unique geological conditions and long-term tectonic evolution, it has abundant and diverse geological heritage resources (XIAO Gui-zhen *et al.* 2007).

The topography and landform within the county are relatively simple. It is mainly composed of low mountain and hilly areas, alluvial plain The terrain of Shunping County gradually drops from the northwest to the southeast. Two major rivers, Jie River and Tang River, run through the mountain area and form a series of valleys and river landscape belts. In terms of geotectonic units, the area is situated at the contact zone of Shanxi fault uplift and Yanshan fold belt in the Sino-Korean para-platform (WANG Hong-lei *et al.* 2016). The strata expose in this area are mainly carbonate rocks of the Precambrian, Cambrian and the Ordovician, localized Pre-Sinian gneisses, as well as unconsolidated sediments of the Paleogene and Quaternary periods.

The tectonic movements of multiple periods and in different directions have created abundant and diverse landscapes in relation to crust tectonics, especially those derived from the Indo-China movement, Yanshan movement and Himalayan movement. As a result, large-scale NEE and E-W trending reverse faults and NE trending normal faults are overwhelming, with some small-scale NW and SN trending faults over the county. Folding structures in the area are dominated by NEE and E-W ones with axial plane dipping to SE (Fig. 1) (XING Wei-guo, 2009).

The thick carbonate rocks have formed unique karst landscapes such as canyon, cliff, mountain peak, stela, karst cave, pictographic rock and *etc*, which are geomorphologically typical in northern China and important tourism resources of Shunping County.

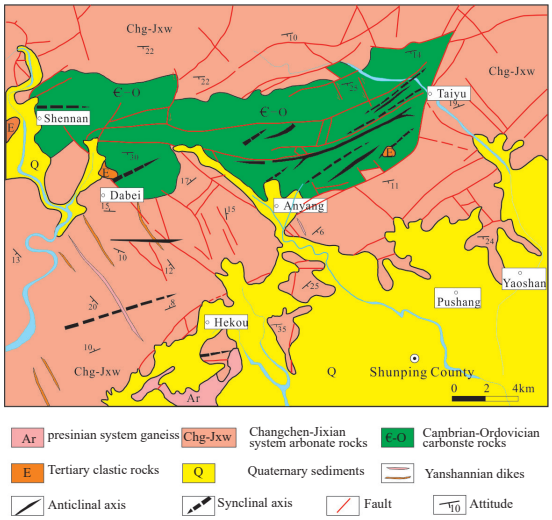

Fig. 1 Geological sketch of Shunping County (modified after XING Wei-guo, 2009)

2 Types of geological heritage in Shunping County

According to the specification for geoheritage investigation, the geological heritage in Shunping County can be divided into 3 categories, 10 classes and 17 subcategories (Table 1). The heritages in the county include all five classes of basic geological category, four classes of geomorphologic landscape category, and one class of geohazard category. The characteristics and spatial distribution of these geological heritages are discussed as follows.

(1) There are a large number of geological heritages with different types.

The geological heritage is in large quantities and high concentration in Shunping County, comparing with that of other country (DENG Ya-dong *et al*. 2019). The landscape of the study area is very representative in the Taihang Mountain area, which contains almost all the typical geo-heritage subcategories (WANG Hui *et al*. 2018) (Fig. 2).

(2) The geomorphologic landscape is the dominant geoheritage, which is valuable and essential for tourism development.

Table 1 Classification of geological relics in Shunping County, Hebei Province

Category (I)	Class (II)	Subcategory (III)	Number
Basic geological type (12)	Stratigraphic section (1)	Typical section (1)	33
	Rock section (1)	Intrusive section (1)	
	Structural section (6)	Unconformity surface (2)	
		Folding and deformation (2)	
		Fracture (2)	
	Important fossil site (1)	Fossil site of ancient plants (1)	
	Important source of rock and ore (3)	Typical ore deposit outcrop (1)	
		Mining sites (2)	
Geomorphologic landscape type (19)	Rock-soil landform (9)	Karst landscape (9)	
	Water body landform (7)	River (2)	
		Lake (1)	
		Waterfall (1)	
		Spring (3)	
	Glacier landform (1)	Ancient glacial relic (1)	
	Tectonic landform (2)	Canyon (2)	
Geohazard type (2)	Geological hazard (2)	Landslide (1)	
		Ground collapse (fissures) (1)	

19 geoheritage sites fall in the geomorphologic landscape category which have great scenic value, accounting for 57.6% of the total geological heritage resources in Shunping County (Fig. 2a). Among them, the rock-soil landforms and water body landforms are of great potential for tourism purpose. So far, only limited geological heritages have been developed into scenic spots, which include the beautiful Sanmiao Peaks with the presence of abrupt and grotesque rocks, the deep and tranquil Zhaigou valley with gurgling flow at the bottom, the large and magnificent pothole group in Baiyintuo Mountain, and the clear and mysterious winding Tang River. However, many other geological heritage resources leave undeveloped, such as the magnificent stone pillars of Wanqing Mountain, various forms of karst caves and *etc*; they are all of great view value and large potential for tourism development.

(3) Distribution concentrates with distinct regional differences.

The geological heritage in Shunping County has relatively concentrated distribution characteristic with obvious regional differences. These resources are mainly distributed in the middle-low mountain and hilly areas, which contain all the 10 heritage classes. However, the number of geological heritages on alluvial-diluvial plain is limited, with only one geological hazard. In respect of spatial distribution, most of the geological heritages mainly occur in Shennan Town, located in the northwest of the county. Meanwhile, some of the heritages appear in Dabei Town, Anyang Town and Hekou Town, with few ones in Taiyu Town and Yaoshan Town (Fig. 2b).

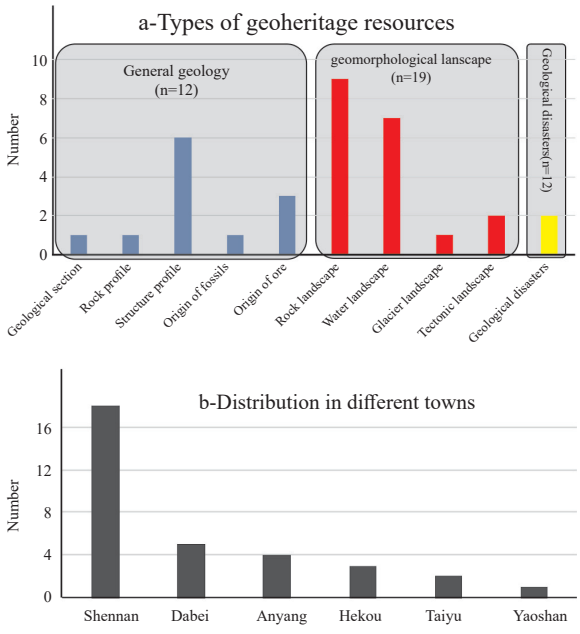

Fig. 2 Characteristics of geological heritage distribution in Shunping County

3 Assessment of geological heritage resources in Shunping County

The assessment was done with reference to the

geoheritage assessment at a county and municipal level (DENG Ya-dong *et al.* 2018), for which multiple factor and quantitative evaluation approach was used.

The quantitative evaluation includes two components, *i.e.* geoheritage value evaluation and geoheritage environment evaluation. According to the specification for geoheritage investigation (Ministry of Land and Resources, 2017), the indexes of the former include (1) scientific value, (2) aesthetic value, (3) rarity, (4) integrity, (5) preservation degree and (6) protectability, while the indexes for the latter contain (7) accessibility, (8) exploitability, (9) historical and value values and (10) safety. The level of each geoheritage site is determined by the combination of points of different evaluation factors and ranks with assessment of associated categories. On this basis, the evaluation results are listed in Table 2.

Table 2 Evaluation criteria and result of geological heritage in Shunping County

Evaluation model	Weighted score	Evaluation factor	Point of different ranks			Weight of different types		
			Below the provincial level	At the provincial level	Above the provincial level	Basic geological type	Landform landscape type	Geological hazard type
Value comprehensive assessment	80	Scientific value	<4	4~7	7~10	3	1	2
		Aesthetic value	<4	4~7	7~10	1	3	1
		Rarity	<4	4~7	7~10	1	1	1
		Integrity	<4	4~7	7~10	1	1	2
		Preservation degree	<4	4~7	7~10	1	1	1
		Protectability	<4	4~7	7~10	1	1	1
Condition comprehensive assessment	20	Accessibility	<2	2~4	4~5	1	1	1
		Exploitability	<2	2~4	4~5	1	1	1
		Historical and cultural value	<2	2~4	4~5	1	1	1
		Safety	<2	2~4	4~5	1	1	1

The level of geological heritage can be divided into three ranks: Above the provincial level, at the provincial level, and below the provincial level. The specific classification criteria are described as follows:

Above the provincial level: Geological heritage with outstanding values and national or regional (cross-provincial) significance with a comprehensive score of 70~100.

At the provincial level: Geological heritage with prominent value and regional significance for province with a comprehensive score of 40~70.

Below the provincial level: Geological heritage with general value and regional significance for city and county with a comprehensive score of < 40.

The result shows that there are 2 heritage sites as above the provincial level (6%) which are potholes and glacial landform in Baiyintuo scenic spot, 14 heritage sites as provincial level (42%), and 17 heritage sites as below the provincial level (52%).

4 Value of geological heritage resources

Geological heritage resources in Shunping County are non-renewable natural resources which have experienced a long term evolution driven by internal and external geological forces. They are of great significance in terms of earth science value, aesthetic value, cultural value, ecological value and public education value.

4.1 Earth science value

(1) Baiyintuo glacier geoheritage

The major features in the Baiyintuo paleo-glacial relic include moulins, sheepback stones, glacial boulder and *etc*. It is one of the two geoheritage sites in Shunping County identified during the previous geoheritage survey in Hebei Province (ZHANG Zhao-yi *et al.* 2018). In fact, the presence of many moulins in the middle-low mountain areas of Hebei Province was already reported by HAN Tong-lin *et al* (1999). However, it is yet uncertain whether or not they are the relics of paleo-glacier (LV Hong-bo *et al*. 2010; SHI Ya-feng, 2010). It is hence necessary to conduct a further investigation into the glacial remains in this area, from which the new findings will be helpful for the study of paleo-glacial activity in eastern China.

(2) Structural peak forest

The presence of karst peak cluster and peak forest, in the vicinity of Longtan Lake (Fig. 3a) and Sanmiao Mountain (Fig. 3b) in the northwest of Shunping County, is a result of long-term geological evolution that the carbonate rocks of the Mesoproterozoic Gaoyuzhuang Formation and Wumishan Formation has experienced. The feature of these karst landscape is similar to the structural peak forest of marble in the Baishishan national geopark located in adjacent Laiyuan County. It is a unique landscape in China of important scientific value (NIE Ze-tong *et al*. 2002; LI Ying *et al.* 2009).

(3) Important mineral resources

Resulting from weathering and leaching of country rocks, the mineral resource is represented by the porcelain clay deposit in Dalinghou Village of Shunping County, which is highly representative in the northern area of the Taihang Mountain as an important mineral resource (TIAN Teng-fei, 2016). The clay deposit, containing minerals as kaolinite, montmorillonite and illite, was formed through the hydrolyzation of acidic dikes consisting of quartz albite porphyry in the condition of low pressure and low temperature. The dykes are intrusive rocks formed in the period of the Yanshan tectonic movement. The porcelain clay deposit in Shunping County is distributed in the NWW direction along the dike (Fig. 3c), with a length of about 10 km. These sites are ideal for the study of characteristics and genesis of the porcelain deposits in the area.

4.2 Aesthetic value

(1) Pothole group

There are 15 potholes that appear in a beading shape or a gourd shape in the 3 km long canyon of the Baiyintuo scenic spot. Each pothole is mostly round and partially oval with smooth walls similar to huge natural bathtub. The largest pothole has a diameter of 5 m and a depth of 6 m in the shape of a pot with a small mouth but a large belly (Fig. 3d). A great number of potholes in large scale with the impressive beauty can be compared with the pothole landscape in some other national geological parks (YANG Tao *et al.* 2015; PAN Ya-hui *et al.* 2016). In a word, this kind of geoheritage is rare in the north China and has important aesthetic value.

(2) Carbonate rock landform

The bedrock exposed in Shunping County is mainly composed of carbonate rocks, which provides basic condition for the development of karst landforms. There are in total ten karst geoheritage sites identified in this survey, accounting for about 30% of all the geoheritage sites. Among them, some sites with prominent karst features have been developed into scenic spots, such as the Xingtanggou Class 3A Tourist Spots. However, the Niumowang cave in Anyang Village and the light-through cave and stone pillar in Wanqingshan Village (Fig. 3e), with magnificent landscape and great potential for tourism, are yet undeveloped.

4.3 Cultural value

(1) Jie River

One of the important rivers in Shunping County is Jie River, which is originated from the Baiyinwa Village in the east of Yi County. It passes through Longtan Lake and flows into Daqing River. The river landscape belts and the terraces along the river are not only valuable resources, but also suitable living localities with a long history (Fig. 3f). During the Warring States Period (475 BC to 221 BC), the Jie River used to be the boundary between the states of Yan and Zhao. In the 1960s, the Longtan Lake and associated irrigation canals were built along the Jie River, presenting the spirit of "self-reliance and hard struggle" of the people in Taihang Mountain area.

(2) Yiqi Mountain

It is said that Shunping is the hometown of Emperor Yao, which has been an important

travelling mark around the local places. According to historical records such as "The Records of the Grand Historian" and "The Bamboo Annals", Emperor Yao was born in Yiqi Mountain of Shunping County, establishing the foundation of the Yao culture. In the Yiqi Mountain, there are Yaomu cave and Yaomu spring, respectively, of which the former is actually a light-through cave developed from the erosion of carbonated rocks. In the light-through cave, the karst features are well developed, which add much to the cultural and ornamental values of the geoheritage site.

4.4 Ecological value

Due to the unique environments of topography, climate, soil and water, lush grasses and dense forests have been booming, which forms a favorable vegetation system in the area. This made the Guanyintang and Niangnianggong Villages in Shennan Town selected as the first batch of National Forest Village in 2019. The good ecosystem has brought to the area considerable tourism resources in different seasons. For example, the peach blossom festival in the spring has been successfully held for 20 years. In autumn time, the Baiyintuo scenic spot is an ideal place to view red leaves, where the red leave festival has been successfully held for 13 years. Both of the festivals are becoming an effective tourist sign. festivals in the county. In addition to the agreeable climatic condition, the superior ecosystem, characterized by large quantity of erosion surfaces, river terraces and alluvial plains in the front of Taihang Mountain, have yielded soils and water of high quality for agricultural activities. As a result, 99.39% of the cultivated lands without heavy metal contamination in the area can be used to development green agriculture and associated green food production.

4.5 Public education value

The knowledge of geological heritage in Shunping County involves many geological disciplines, including sedimentology, stratigraphy, structural geology, quaternary geology, geomorphology, mineralogy, paleontology and *etc*. The geological phenomena and their connotations can be intensively displayed to the public, especially to the students to enhance their geo-scientific awareness. In addition, some geological disasters have been found in the transition zone between the mountain and plain, such as the landslide in Lisizhuang and the ground fissure in Yaoshan Town, can be be used as representative geohazard education sites.

On the other hand, the basic research and the protection of geological heritage resources in Shunping County are limited. In recent years, geological heritage resources are affected in different degrees due to the development of quarries and other illegal mining activities in the mountain areas. For example, the pictographic rocks in Pianluoyu Village have been suffered from destruction (Fig. 3g). It is strongly suggested to establish unified identities and governance measures for effectively protecting and managing the geological heritage resources as soon as possible.

5 Conclusions

The geological heritage resources in Shunping County, Hebei Province are diverse and prominent in terms of resource types and features. On the basis of detailed resource survey, there are in total 33 geological heritage sites with great potential and values for the development tourism industry. The investigation result shows that the geoheritage resources are typical in the area of Taihang Mountain. For the resource quality assessment, the method of multi-factor quantitative evaluation was used. Analytical result shows that there are 2 geological heritage relics falling above the provincial level, 14 sites at the provincial level and 17 ones below the level. These sites are of great value in scientific research, scenic tourism, cultural inheritance, ecological conservation and scientific popularization. It is suggested that the local government should not only protect the geological heritage resources, but also conduct in depth study, scientific planning and rational exploitation in combination with the values of geological heritage resources, so as to promote local economic development.

Acknowledgements

This work was supported by the China Geolo-

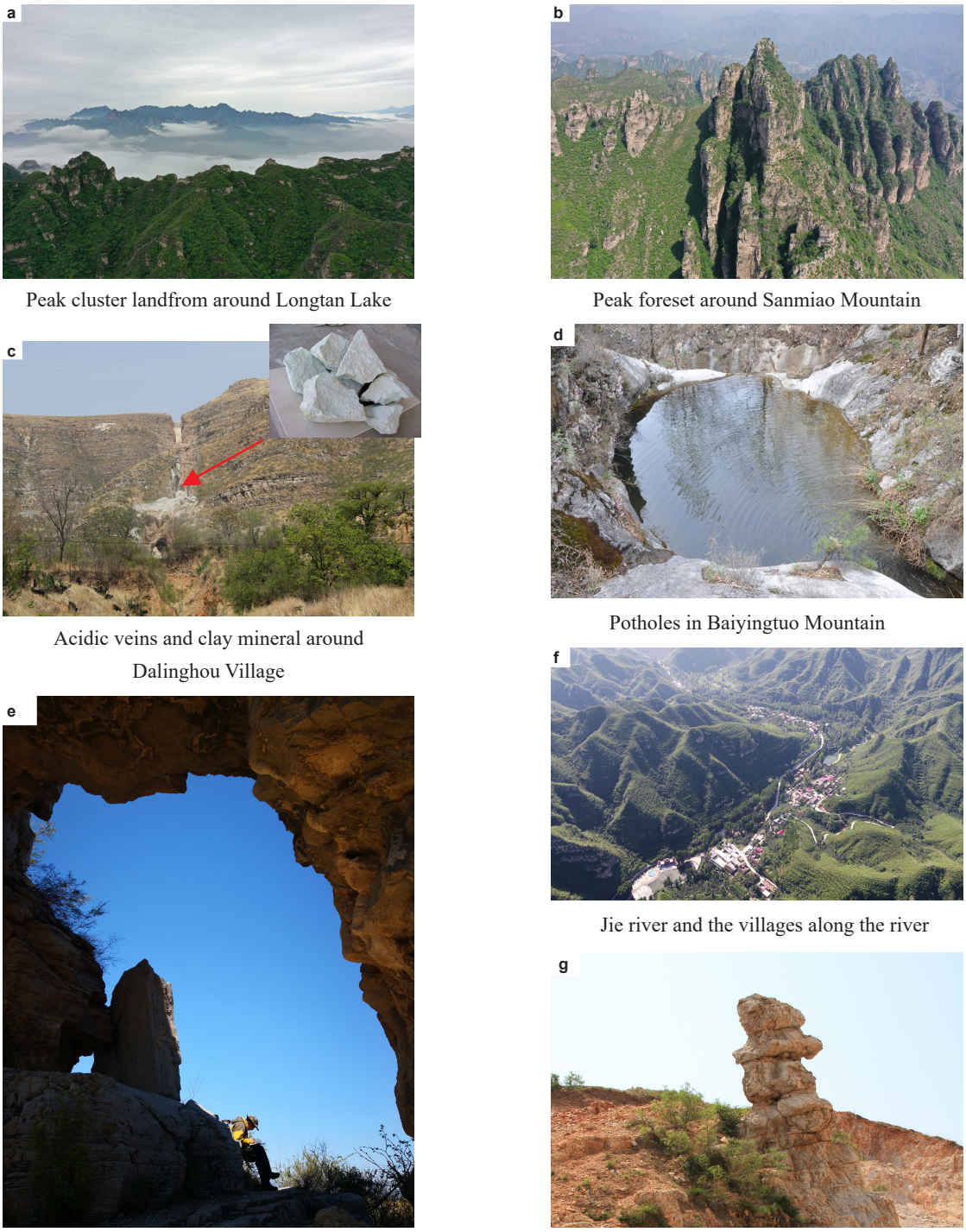

Fig. 3 Representative photos of geological heritage in Shunping County

gical Survey project (No. DD20190555) and the People's Government of Shunping County.

References

CHEN Bin, YIN Xian-ya, SONG Yun, *et al*. 2019. Geoheritage characteristics and development suggestions of Sanggan River Geopark in Hebei Province. Natural Resource Economy of China, 32(11): 69-75. Doi: 10.19676/j.cnki.1672-6995.0000278.

DENG Ya-dong, LUO Shu-wen, SHI Wen-qiang, *et al*. 2018. Comprehensive value evaluation of geological heritage resources based on township division: Taking Yanjin County as an example. Carsologica Sinica, 37(06): 932-

939. Doi: 10.11932/karst20180613.

DENG Ya-dong, SHI Wen-qiang, LUO Shu-wen, *et al*. 2019. Value evaluation of typical geological heritage landscape in Yanjin County. Journal of Guilin University of Technology, 39(03): 599-605. Doi: 10.3969/j.issn.1674-9057.2019.03.008.

DING Hua, ZHANG Mao, LI Xiao-nan, *et al*. 2020. Geological culture village: Scientific connotation, construction content and implementation path. Geological Review, 66(01): 180-188. Doi: CNKI: SUN:DZLP.0.2020-01-016.

DONG Ying, CAO Xiao-juan. 2019. Innovation and application of survey and evaluation method of national important geological relics resources. Management and Research on Scientific & Technological Achievements, 3: 70-72. DOI: 10.3772/j.issn.l 673-6516.2019.03.026.

FU Yin-hong.2020. On the geological landscapes heritages and their significances of West Lake and its surrounding area in Hangzhou. Geological Review, 66(2): 475-484. Doi: CNKI:SUN:DZLP.0.2020-02-019.

HAN Tong-lin, LUO Xiong, GUO Ke-yi. 1999. Rare moulin swarms discovered in the Medium-Low Mountains areas in Hebei and Inner Mongolia. Geological Review, 05: 456-462. Doi: 10.1088/0256-307X/15/11/025.

LI Yan-chen. 2018. Accelerating the development of geoscience tourism to support the whole region tourism. Hebei Geology, 3: 26-29.

LI Ying, CHEN Kui-gang, GUO You-zhao, *et al*. 2009. Magmatic activities in Taihang Mountain area control the formation process of peak forest zhanggu landform. Journal of Changchun Institute of Engineering (Natural Science Edition), 10(01): 81-84. Doi: 10.3969/j.issn.1009-8984.2009.01.024.

LV Hong-bo, REN Xiao-hui, XU Min, *et al*. 2010. On the meltwater origin of potholes found on Granite Ridges-a consultation with academician SHI Ya-feng. Geological Review, 56(05): 693-702. Doi: CNKI:SUN:DZLP.0.2010-05-013.

Ministry of Land and Resources, PRC. 2017. Code for geological heritage survey (DZ/T 0303-2017).

NIE Ze-tong, LIANG Ding-yi, ZHAO Chong-he, *et al*. 2002. A new type of geological-geomprphological landscape: The Baishi Mountain marble structural "peak forest" (hoodoos) and its origin. Geological Bulletin of China, 06: 357-362. Doi: 10.3969/j.issn.1671-2552.2002.06.014.

NIU Ping-shan, YANG Xiao-hui, WANG Yan-hua, *et al*. 2004. Discussion of peasant cooperative economy. Journal of Shijiazhuang University of Economics, 27(2): 175-178. Doi: 10.3969/j.issn.1007-6875.2004.02.015.

PAN Ya-hui, FAN Ping, FENG Hang-jian. 2016. Geological relic landscape resources in Dapanshan geopark and it's tourism development. Bulletin of Science and Technology, 32(04): 42-47. Doi: 10.3969/j.issn.1001-7119.2016.04.010.

SHI Ya-feng. 2010. Comments on the moulin argument provided by Mr. HAN Tong-lin, a misunderstanding of granite negative spheroidal weathering. Geological Review, 56 (03): 351-356. Doi: http://ir.casnw.net/handle/362004/19921.

TIAN Teng-fei. 2016. A brief analysis on the geological characteristics and genesis of Majiayu Porcelain clay deposit in Tang County. Guide to China's Non-metallic Minerals Industry, 03: 48-50. Doi:10.3969/j.issn.1007-9386.2016.03.018.

WANG Hong-lei, LI Wei, WU Hong-tao. 2016. The storage water structure and water-seeking direction on Shunping County. Shanxi Architecture, 42(12): 45-47. Doi: 10.3969/j.issn.1009-6825.2016.12.025.

WANG Hui, LI Jiang-hai, WU Tong-wen. 2018. Characteristics and genesis of geoheritage resources of Taihang Mountain. Acta Scientiarum Naturalium Universitatis Pekinensis, 54(03): 546-554. Doi: 10.13209/j.0479-8023.2017.098.

XIAO Gui-zhen, WEI Fen-hua, ZHAO Xun. 2007. Research on the formation background, development and protection of geological tourism resources in Hebei Province. Beijing: Geological Publishing House: 60-63.

XING Wei-Guo. 2009. Stotaage environments and exploration methods of groundwater in Western Baoding Mountainous Region. Ph.D. thesis. Beijing: China University of Geosciences (Beijing).

YANG Tao, YU Ji-tao, WANG Je-an, *et al*. 2015. Effect of neotectonic movement on the geological heritage landscape of Guanshan

national geopark. Journal of Hubei University for Nationalities (Natural Science Edi-tion), 33(03): 342-346. Doi: 10.13501/j.cnki.42-1569/n.2015.09.029.

ZHANG Huan-xin, CAO Jun, ZHANG Chenggong, *et al*. 2018. Types and values of geological heritage resources in Keketuohai UNESCO Global Geopark. Geological Review, 64(02): 447-449. Doi: 10.16509/j.georeview.2018.02.016.

ZHANG Zhao-yi, XU Yong-li, YANG Hong-bin, *et al*. 2018. Investigation report of important geological relics in Hebei Province.

ZHONG Zi-ran. 2018. More efforts to do traditional geology, more beautiful to construct blue streams and green hills. Geological Review, 64(1): 12-14. Doi: 10.16509/j.georeview.2018.01.020.