



Geoheritage and Sustainable Development in Yimengshan Geopark

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Abstract

The protection of geoheritage, popularization of geoscience, sustainable development of local society, and economic growth are the most important reasons for establishing a UNESCO Global Geopark. Yimengshan Geopark is an aspiring UNESCO Global Geopark. To date, no study has comprehensively described its geoheritage or put forward suggestions about its protection, sustainable development, and community involvement. In this paper, the geoheritage in Yimengshan Geopark is thoroughly investigated and described based on the classification of stratigraphic vestiges, rock relics, tectonic vestiges, landforms, water bodies, cultural significance, and other aspects. To achieve this analysis and address existing problems, a comprehensive SWOT analysis is conducted to examine variable situations. Further suggestions are subsequently put forward about the protection of geoheritage, education programs, geotourism, and sustainable regional development of this geopark. Finally, the prospect of the sustainable development of the geopark is briefly described.

Keywords Geoheritage · SWOT analysis · Sustainable development · Yimengshan Geopark

Introduction

Since the new label of UNESCO Global Geopark was ratified in 2015, the interest in geoheritage and geology focused on geotourism has increased rapidly in China, especially in less developed areas. Geotourism is becoming an important source of income in many rural areas (Brocx and Semeniuk 2007; Dowling 2011). The Chinese government has determined to boom the regional economy through tourism, which is exactly consistent with the goal of UNESCO Global Geopark (UGGp) to promote sustainable development of geopark territory. In fact, UGGps do play a very important role in promoting local sustainable development and attracting a great many tourists. The Chinese government and residents have

already reached consensus in establishing UGGps, and hope to achieve geoheritage preservation and regional sustainable economic development depending on geoparks. Therefore, geoparks in China have positively applied to join the UGGp family, although China has already had 37 UGGps (a quarter of the total number of UGGp in the GGN). The sustainable development of the local economy is as important as geoheritage with global significance when applying for UGGp (UNESCO 2016). Yimengshan Geopark is an aspiring UNESCO Global Geopark characterized by abundant and unique geoheritage and cultural resources, which meet the basic requirements of establishing UGGp. Yimengshan Geopark is located in Linyi City, Shandong Province, with a total area of 1804.76 km² (Fig. 1). Yimengshan Geopark is located on the Luxi Block to the west of the Yishu fault zone. This area contains very old strata, and an Archean massive intrusive rock series records the evolution of the early crust in North China. The primary diamond mine used to yield diamonds up to 1,800,000 karats, and this area is also the type locality of the Daigu (castle-shaped) landform. Even if an area has an outstanding geoheritage of universal value, the area cannot be considered for inclusion in the UNESCO Global Geoparks unless the area has a plan for the sustainable development of the people living there (UNESCO 2016). Based on thoroughly geoheritage investigation and description, and the requirements from the UGGp assessment (Evaluation Document A), a comprehensive SWOT analysis is conducted

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Fig. 1 Location of Yimengshan Geopark

to examine variable situations in the geopark. Further suggestions on the protection of geoheritage, education programs, geotourism, and sustainable regional development are put forward for itself and other geoparks.

Categories and Descriptions of Geoheritage

There are many types of geoheritage in Yimengshan Geopark, such as the Taishan Rock Group and komatiite, which represent stratigraphic vestiges; intrusive rocks and faults caused by multiple tectonic movements and unconformable contact relationships between strata, which represent tectonic vestiges; Daigu landforms, which represent landform landscape relics; and rare kimberlite mine heritage units; furthermore, the water bodies in the area include lakes and waterfalls. There are many kinds of geoheritage in Yimengshan Geopark, 44 of which are representative (Table 1). In terms of specific functions, there are 18 geoheritage of important scientific value, 37 geoheritage for popular science education, and 29 geoheritage for geotourism. In terms of scientific significance, there are 5 geoheritage of global significance, 11 geoheritage of national value, 10 geoheritage of regional value, and 18 geoheritage of local value (Fig. 2).

The geoheritage of global significance within Yimengshan Geopark can be divided into four composite categories: the Taishan group; intrusive rocks of various stages that formed

during the early phase of crust formation; kimberlite primary diamond ore deposits; and Daigu landforms (Fig. 3).

Stratigraphic Vestiges

Taishan Rock Group

The Taishan Rock Group comprises some of China's oldest strata. The Western Shandong Greenstone Belt, which is the best preserved and most completely developed typical Neoproterozoic greenstone belt in this region, occurs within the granite-greenstone zone in western Shandong (Meng et al. 2016). This group has undergone low- to medium-pressure metamorphism. One particular feature of this group is that its basic volcanic rocks exhibit no obvious migmatization (Yanlingguan Formation). From bottom to top, the Taishan Rock Group comprises the Yanlingguan Formation, Shancaoyu Formation, and Liuhang Formation (Table 2).

Regionally, the Taishan Rock Group is distributed across the Yanlingguan, Liuhang, Hanwang, and Jieshou belts in a NW-trending monoclinical manner. These strata represent residual units within the vast gneissic granite zone. This group crops out most favorably in the Yanlingguan-Shancaoyu-Liuhang area of Xintai City. Exposures are also present near Sujiagou and Panchegou in Mengyin County. The lower greenstone within the greenstone belt shows significant lateral variation. The overlying clastic rock formations also vary widely.

Table 1 List of the main geoheritage in Yimengshan Geopark; their locations are shown in Fig. 2

Name	No.	Description	Value
Stratigraphic sites			
Taishan Group	23		Global
Komatiite	9		Global
Rock relics			
Tonalite	18	Wangfushan rock mass, Taishan suite	Global
Tonalite (coin-shaped stone)	17	Xiguanzhuang rock mass, Taishan suite	National
Trondhjemite (vein)	31	Xinfushan suite	
Granodiorite	32	Guimengding rock mass	National
Monzonitic granite	41	Aolaishan suite	National
Boundary line of the Guimengding rock mass and adamellite of Aolaishan Suite	30		National
Ink Slab	33	Potholes	
Niulan diabase	42		National
Medical stone	19	Porphyritic granodiorite	
Tectonic sites			
Mengshan faults	22	Outcrops	National
Precambrian and Cambrian Series unconformities	1		National
Xianhulou	5	Joint and natural bridge	
Joint	43	Rock cleavage	
Faults	25		
Kimberlite			
Shengli No. 1 kimberlite pipes and outdoor mine pits	15		Global
Hongqi No. 1 rock vein mine pit	13	Discovery location of kimberlite	National
Shengli No. 2 kimberlite vein	14		National
Diamond ore production site	16		
Landforms			
Ban Gu	7		
Tuanyuan Gu	2		Global
South Daigu	4		
North Daigu	3		
Tashan	10		
Yaoshan	11		
Matou Gu	21		
Peak Yingwo	26		National
Peak Tianhu	34	Pictographic rock	
Turtle Going out to Sea	24	Pictographic rock	
Balanced Rock	36	Pictographic rock	
Golden Peach Rock	44	Inclusions	
Tearing Crocodile	37	Caves and veins	
Spheroidal weathering	38		
Brush Stand Peak	35		
Xingshan Cavern	20	Marl cavern	
Underground Milky Way	8	Limestone cavern	National
Paleontological sites			
Stromatolitic limestone	6		
Water bodies			
Chinese map-shaped waterfall	40		
Yunmenghu Lake	12		
Three Longmen Pools	28		
Shipuya	29		
Yuquanzhenliu	27		
Total	44		

Rock Relics

Intrusive Rocks of Various Stages from the Early Phase of Crust Formation

The mainly granitic intrusive rocks of Yimengshan Geopark come from early Precambrian strata. This geopark is one of the few classic regions in China that exhibits the extensive

distribution of typical gneiss, with two TTG suites and potash granite that were formed by strong magmatic activity during the early, middle, and late Neoproterozoic (Wang et al. 2015a, b). These rock masses, which formed at various times, represented the early crust. Good geological bodies dating from the late Proterozoic and “transformation period,” as described by the International Commission on Stratigraphy, are preserved in this region. These bodies have great scientific significance

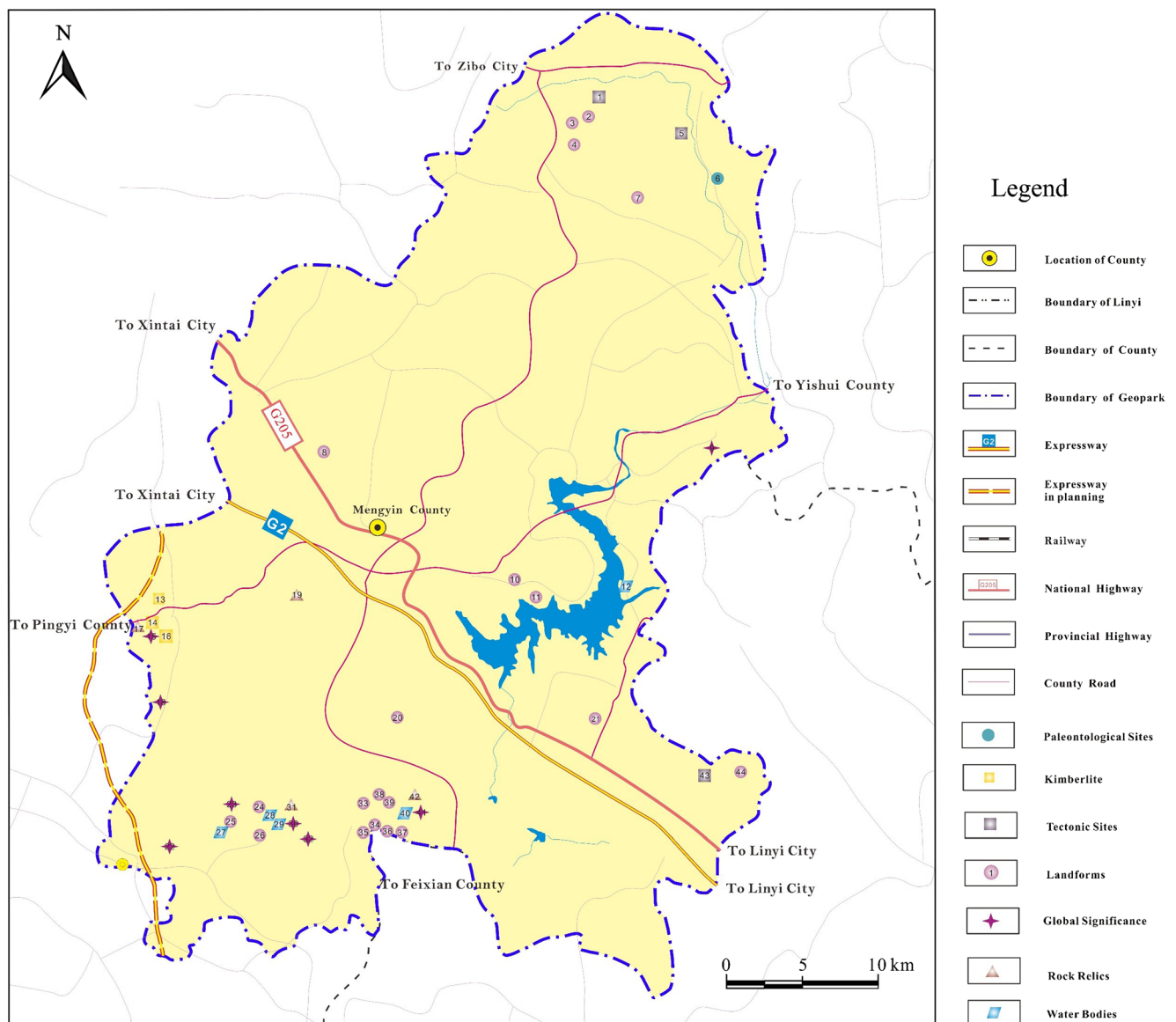


Fig. 2 Locations of the main geoheritage in Yimengshan Geopark

for studies of the various stages of Archaean intrusive rocks and their relationships with intrusions, exploratory research on the mass formation of Archaean granite, investigations of craton formation and the early stage of crustal evolution, and the construction of a global geological framework for Precambrian tectonics (Table 3).

The Wangfushan Unit banded fine-grained tonalitic gneiss, which crops out 500 m west of Beiliujiazhuang Village, Mengyin County, has been dated to 2664 ± 13 Ma. Within this rock is a Yanlingguan Formation fine-grained amphibolite remnant of the Taishan Rock Group that is 20 cm in diameter. There are abundant pegmatite veins that are approximately 4–5 cm wide. These pegmatite veins have been dated to 2606 ± 9 Ma. An obvious transect relationship that formed between these rocks during three different periods can be observed. Nicknamed “A Family of Three Generations”

by geologists (Fig. 3b), this unit represents a very rare geological phenomenon. The Wangfushan Unit of the Taishan Rock Group forms the earliest and largest western Shandong craton in North China. This unit is highly significant for research of early crustal evolution (Wang et al. 2015a, b; Meng et al. 2016).

Komatiite

The komatiite of this rock group is the only Archaean ultrabasic extrusive rock with spinifex texture in China (Fig. 4a). The ultramafic rocks cropping out in the greenstone belt, including actinolite tremolite schist and talc-serpentinite, are all komatiites. These komatiites exhibit close co-existing relationships with tholeiitic basalt, and intermediate-acidic volcanic sedimentary rock is also

Fig. 3 Geoheritage sites with global significance value in Yimengshan Geopark. **a** Remnant of the Taishan Group. **b** “A Family of Three Generations.” **c** The Shengli No. 1 kimberlite rock pipe and open pit mining site. **d** A panorama of the Daigu Landform



present. There is a rare outcrop of komatiite with spinifex texture in Sujiagou, within the Yimengshan Geopark Area (Wang et al. 2015a, b). This outcrop is approximately 100 m wide and trends 60°.

Tectonic Vestiges

Contact Boundary Line Between Rock Masses

The bed of the Jingtian River extends along a contact boundary line between the Guimengding rock mass, which intruded at 2540 Ma (gneissic granodiorite), and the Aolaishan rock mass, which intruded at 2520 Ma (medium-grained porphyritic biotite monzonitic granite). The orientation of the contact

boundary line is 165°. The contact between the rock masses that formed during these two periods is clearly visible. The relatively gentle riverbank in the west is part of the Guimengding rock mass, in which dark remnants can be observed. The Aolaishan rock mass is located on the east riverbank, which is steep (Fig. 4b).

Joints

Split in the middle, this giant rock is actually monzonitic granite cleaved open by joints formed by tectonic activity. The cleavage in this rock looks very similar to a cut made by a knife or hatchet (Fig. 4c). Joints are related to the formation of many geomorphologic landscapes.

Table 2 Stratigraphy of Taishan Rock Group in Yimengshan Geopark (adapted from the Regional Geology Annals of Shandong Province, 2012)

	Location	Formation	Rock	Thickness	Bedding
Taishan Rock Group	Top	Liuhang Formation	Chlorite schist Biotite granulite Amphibole biotite granulite Sericite-quartz schist Intermediate-acidic metamorphic volcanic breccia Metamorphic conglomerate Amphibole magnetite-quartzite		
	Middle	Shancaoyu Formation	Biotite granulite Mica schist Magnetite-quartzite	2110 m	Graded beddings, cross beddings, micrographic beddings
	Bottom	Yanlingguan Formation	Fine-grained to ultrafine-grained amphibolite Amphibole granulite Biotite granulite Mica schist Actinolite tremolite schist Metamorphic conglomerate, magnetite-quartzite	200–1430 m	

Table 3 Intrusive rocks of various stages

Era	Period	Suit	Unit	Rock type	Age (Ma)
Neoproterozoic	Late	Aolaishan	Songshan	Medium-grained monzonitic granite	2516
		Fengshan	Guimengding	Gneissic medium-grained biotite-bearing granodiorite	2539
	Middle	Xinfushan	Shanggang	Gneissic medium-grained biotite-bearing trondhjemite	2623
		Early	Taishan	Xiguanzhuang	Gneissic medium-grained biotite amphibole tonalite (coin-shaped stone)
				Wangfushan	Banded fine-grained biotite-bearing tonalitic gneiss

Faults

Influenced by the Indosinian movement, a fault dipping 65° splits the Tuanyuan Gu into one high and one low rock mass. The tops of the east and west Tuanyuan Gu are composed of 20- to 26-m-thick limestone sediment (Fig. 5a).

Unconformable Contact Relationship Between Strata

The contact relationships between the Cambrian and Archaean strata in the geopark are unconformable. The lower part is salmon-pink monzonitic granite from the late Archaean, and the rock above the unconformity is the lower

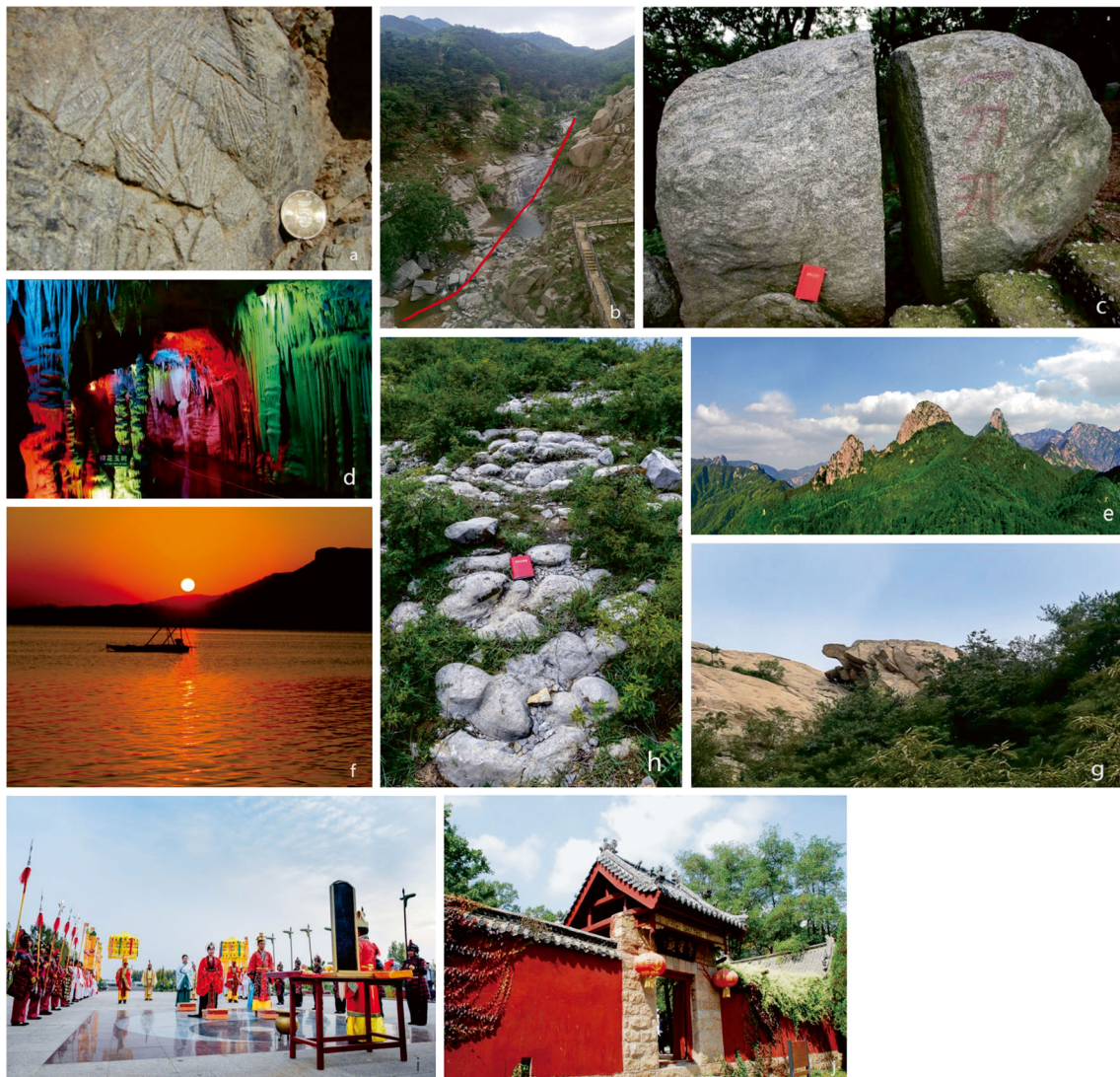


Fig. 4 The main geoheritage in Yimengshan Geopark. **a** Komatiite with spinifex texture. **b** Boundary line of the Guimengding rock mass and monzonitic granite of the Aolaishan Suite. **c** Joints. **d** Limestone

Cavern. **e** Brush Stand Peaks. **f** Yunmenghu Lake. **g** “Turtles Going out to Sea.” **h** Trilobites. **i** Mengshan Mountain longevity ceremony. **j** Rain God temple



Fig. 5 a Faults. b Unconformable contact between the Cambrian and Archaean strata

Cambrian clastic rock. Viewed broadly, the unconformity is undulating and uneven. The salmon-pink monzonitic granite at the bottom formed ca. 2,500 Ma, while the sedimentation of the overlying Cambrian strata began ca. 541 Ma. There is a gap of nearly 2000 Myr between these two units (Fig. 5b).

Kimberlite Primary Diamond Ore

The formation of kimberlite ore deposits requires not only a stable craton but also a reasonably thick sedimentary caprock on the craton underlain by large and buried deep faults. Because deep faults can reach the mantle, kimberlite-bearing magma can intrude upwards through these conduits. The enclosed condition created by the overlying rock can maintain stable temperature and pressure conditions during the magma's ascent, which allows the xenolithic kimberlite to remain stable. When affected by tectonic processes such as faulting, high-temperature and high-pressure magma may explode and intrude to form kimberlite primary ore deposits.

Shengli No. 1 Big and Small Rock Pipes

These pipes are located in the central part of the Changmazhuang rock belt. The large and small pipes are 20 m apart and merge at a vertical depth of 250 m. At a vertical depth of 300–450 m, the two connected pipes are manifested as a northeasterly projecting oxbow that is 130–160 m long and 10–24 m wide. The small pipe is located to the east of the large pipe. The large and small pipes are mainly composed of porphyritic pyrope kimberlite, with smaller amounts of porphyritic kimberlite and small quantities of breccia kimberlite (Wang et al. 2015a, b). The open pit is currently well preserved. This oval pit is approximately 330 m long from east to west and 230 m wide from north to south. There are five slope steps, and the total area exceeds 73,000 m².

Hongqi No. 1 Ore Veins

For the first time in China, kimberlite primary diamond ore deposits of industrial exploitation value have been discovered near the watershed to the northwest of Wangjiacun Village and to the east of Getiaolingcun Village (Fig. 6). This 3- to 6-m-wide by 3- to 6-m-deep pit consists of 16 small mines with tonalitic gneiss wall rock. The underground mining depth is 45 m. The general orientation of the veins is approximately 30°. Their total length is 1450 m. These veins are controlled by an NNE-trending compresso-shear fault and are divided into southern and northern sections by a nearly NS-trending diabase dike. The major mineral ores are porphyritic pyrope kimberlite and fine-grained kimberlite. A pit head for underground mining has been preserved at the northern end of the ore vein.

This mine ranks first in Asia both in terms of its diamond reserve and the scale of its outdoor mining operation. The recoverable diamond deposits within the geopark total 7,850,000 karats. Mengshan No. 1, the diamond monomer this mine produced, is the largest primary diamond in China.

Landform

Daigu Landforms

A gu is a landform unique to the central and southern regions of Shandong. In geomorphology, a gu is a mesa, which was originally called a gu landscape. As these landforms are most concentrated and typical in the township of Daigu in Mengyin County, they were originally named “Daigu landforms.”

Daigu clusters are densely distributed, and they have diverse types, forms, and sizes. In particular, there are more than 30 representative Daigu masses of strong research and ornamental value. As geomorphic features, gu masses have important geological research value and geo-tour potential.

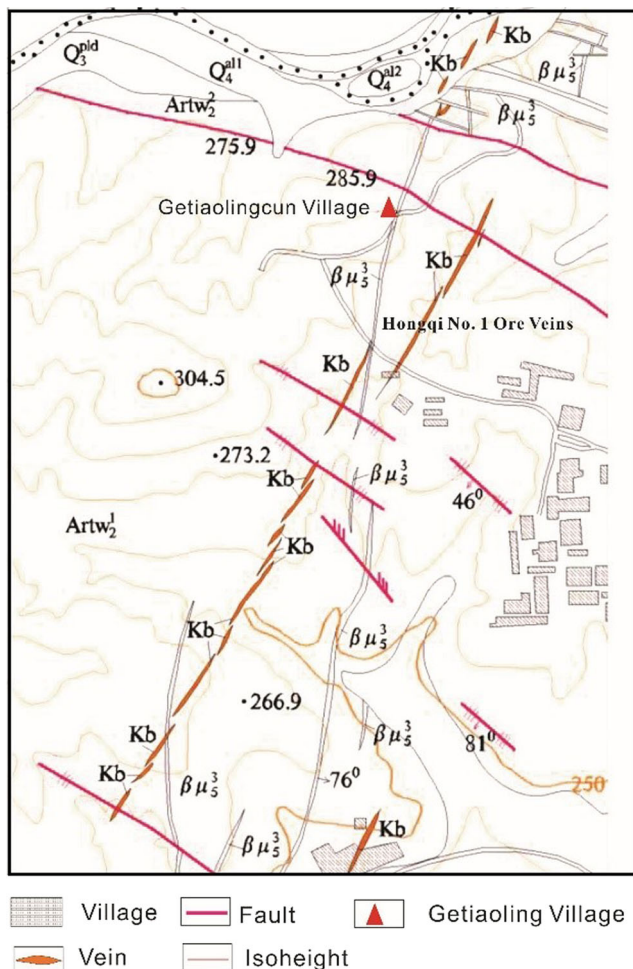


Fig. 6 Location and distribution of the Hongqi No. 1 ore veins

Daigu landforms exhibit archetypal mesa characteristics. A gu usually comprises at least two upper and lower sections that have different rock properties. The top rock is the distinct feature of a mesa. It is highly resistant to weathering and denudation but may contain joints. Exogenic geological processes and gravitation over the ages have led to landslides, reducing the structure to a typical mesa index bed, which exhibits thick bedding, abrupt rock faces, and a flat top. The lower section is generally less resistant to weathering. This rock is also relatively weak, mainly comprising clastic rocks such as mudstone and sandy mudstone, but it sometimes contains alternating mudstone and other thin-bedded rock beds. Overall, the lower section is thicker than the overlying index bed. Affected by persistent weathering, this rock suite will gradually turn into a nearly vertical body with gentle slopes, thus forming a base for the mesa. Daigu landforms are unique because the upper index bed is a suite of Cambrian thick-bedded limestone, and the base comprises clastic rocks such as muddy limestone and silty mudstone, which are vulnerable to weathering (Fig. 7).

Karsts

The karsts in the geopark are best represented by Xingshan Cavern and Limestone Cavern. These caves contain stalactites, subterranean rivers, erosion landforms, and dissolution landforms. The large scales of these caverns, as well as their complete range and high abundance of speleothems, are rarely seen in northern China.

Limestone Cavern

This cavern, which occurs in Ordovician limestone, is the largest and most intact underground karst landscape in Shandong Province. The cavern is more than 10,000 m long and features caves within caves. From top to bottom, there are several layers in this cavern. Speleothems such as stalactites, stalagmites, rock columns, and stone flowers can be found in the deep caves (Fig. 4d).

Peak Dayunmeng and Peak Xiaoyunmeng (Brush Stand Peaks)

Peak Dayunmeng and Peak Xiaoyunmeng make up the Chinese character shan (mountain). It is said that Cang Jie, the inventor of Chinese characters, was inspired by these peaks to create the character shan. These crests are also called Brush Stand Peaks. The 1026-m-high Peak Yunmeng is one of the highest peaks of Mengshan Mountain (Fig. 4e).

Yunmenghu Lake

Yunmenghu is the second largest reservoir in Shandong Province; it is located at the intersection of the Dongwen River and the Zihe River in Mengyin County, with a total capacity of 749 million cubic meters. As a large, multi-purpose reservoir, Yunmenghu is a rich and high-quality water resource, which is an important water supply for Linyi City (Fig. 4f).

Pictographic Rock

Atop a cliff 1000 m above sea level, a granodiorite body was weathered along its joints and gneissosity for a long time. This unit was denuded into a wide range of turtle-shaped pictographic rocks (Fig. 4g).

Paleontological Relics

Trilobites

The Mantou Formation shale contains trilobite fossils. Trilobites first appeared in the Cambrian at 540 Ma and went extinct in the terminal Permian at 250 Ma during mass

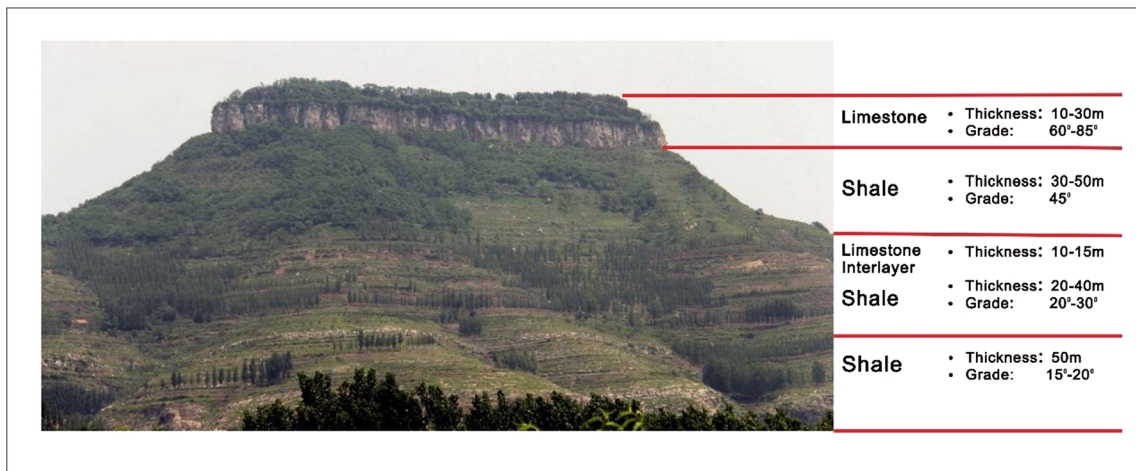


Fig. 7 Sketch map of characteristics and lithology of gu

extinction. The Cambrian marked the beginning and development of modern life. It was also the peak of trilobites. Trilobite fossils represent important evidence for distinguishing and comparing Cambrian strata (Fig. 4h).

Culture

Although geological heritage is the most important component of a geopark, a geopark is neither a theme park nor a geological open-air museum. Geopark areas should include not only geological heritage but also areas of relevant biodiversity and archeological heritage and areas where historical and cultural sites have a connection with local geodiversity (Carvalhido et al. 2016; Žáček et al. 2017). Yimengshan Geopark is characterized by its abundant and unique cultural resources.

Mengshan Mountain Longevity Ceremony

Mengshan Mountain has long been regarded as a sacred land where people come to pray for good health and longevity; here, a tradition of praying for blessings and long life has endured for centuries (Fig. 4i). The Mengshan Mountain longevity ceremony consists of six rituals: celebrating long life, wishing for long life, giving long life, respecting long life, worshipping long life and praying for long life. Today, it is an important ceremony that passes on the culture of longevity and filial piety.

Rain God Temple

Originally built in the Jin dynasty, the Rain God temple has waxed and waned. It is one of the major Taoist temples on Mengshan Mountain (Fig. 4j). The local people in this area strongly revere the Rain God; they hold a grand sacrificial

ceremony on the Rain God’s birthday as well as large annual events.

The rebuilt temple is a grand building featuring ornate cornices and carved roof beams. The Rain God is enshrined in the main hall.

SWOT

Here, SWOT analysis (Dony 2017) is used to evaluate the resources, protection, and development in Yimengshan Geopark (Table 4).

Strengths

Yimengshan Geopark is already a national geopark with a complete infrastructure. The geopark is located only 100 km from the nearest airport and railway station. Two highways, a national road and a provincial road, pass by the geopark, thus providing convenient transportation and high accessibility. As for an aspiring UNESCO Global Geopark, Yimengshan has been devised a series of solutions to protect the geoheritage. Education programs are going well. The relevant content of the geopark has been added to a textbook compilation, and abacus has become an optional course for primary school students. Local schools have started performing classroom activities in the geopark. The geopark has begun cooperating with colleges and universities. Representatives of Yimengshan Geopark have taken part in various activities and attended many international meetings.

Weaknesses

No regular training courses are available for geopark tour guides. The tour guide position has a high turnover rate due to its unsatisfactory salary. Some geoheritage sites have

Table 4 SWOT analysis to evaluate the resources, protection, and development of the study area

SWOT	Remark
Strengths	<ul style="list-style-type: none"> • High geodiversity • Geosite of international geological significance • Measures are taken to protect geosites • Promotion of cultural heritage • Well-equipped infrastructure • Educational materials • Take part in network
Weaknesses	<ul style="list-style-type: none"> • Few training courses for guides • Turnover rate of staff employed by geopark partners is high • Public interpretation is not simple enough • Bad marketing strategy • Too little activities • Lack of promotion for local food • Links between the geopark and local business are weak
Opportunities	<ul style="list-style-type: none"> • Good public accessibility • Services to support geotourism
Threats	<ul style="list-style-type: none"> • Natural denudation and waster • Overlapping management

overlapping signboards. The content on the signboards is sometimes slightly too difficult to understand. The interpretation system is not scientific, and explanations of geological phenomena still include many references to myths and legends. Some geoheritage that do not have strong ornamental value cannot have high economic value. Local agriculture mainly depends on peach, but geopark has not introduced this brand as a geopartner. Community residents have not yet realized the value of geoheritage and still have poor cognition and consciousness regarding protection.

Opportunities

Free public transportation is provided between each area in the geopark and in the form of a shuttle bus from Linyi bus terminal to the entrance of the park. *Travel in Yimengshan* is a type of annual card that is marketed to tourists who live near the geopark.

Threats

This area is not well known outside of Shandong Province compared with Tai Mountain; therefore, the number of tourists is relatively small. Some of the outcrops may be weathered and denuded by natural disasters. Environmental issues may be caused by increasing rural tourism in the geopark. Multiple departments in the geopark are in charge of different types of resources, which can lead to conflicts and the unreasonable use of funds.

Proposal for Sustainable Development

Geoparks are focused on sustainable development and stimulate economic activity through geotourism (Brocx and Semeniuk 2007; Dowling 2011; Uroš and Aleksandra 2018). The promotion of geotourism, when combined with high-quality infrastructure and interactive interpretation, is often an appropriate form of local economic development through community involvement (Wartiti et al. 2008; Farsani et al. 2011; Margiotta and Sansò 2014). Geoparks stimulate socio-economic activity and sustainable development by attracting increasing numbers of visitors (Farsani et al. 2011). In the study area, there are over 405 administrative villages (communities) with a total population of 637,000. In 2017, Yimengshan Geopark attracted 12.3 million visitors, and the total annual tourism revenue was 7.68 billion yuan. This geopark can thus provide a great opportunity to benefit local communities. Figure 8 illustrates the significant increase in tourists that has occurred in this geopark since 2013, as the income from community tourism has increased annually. In 2015, this geopark experienced rapid growth after being recommended as an aspiring UNESCO Global Geopark by the Ministry of Land and Resources; however, further improvement is still needed.

Data source: the Yimengshan Geopark Administrative Committee

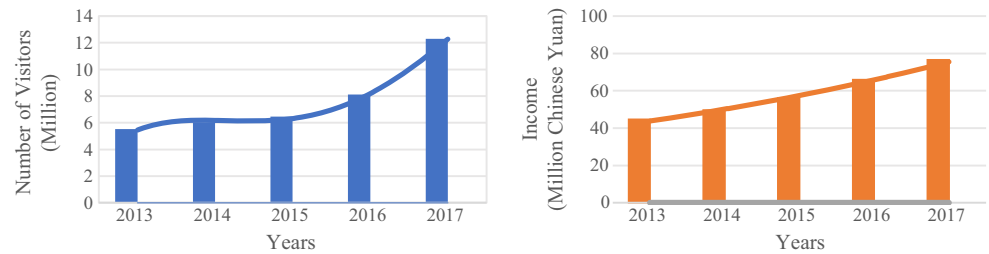
Following the SWOT analysis and adopt criteria in “Evaluation Document A,” further proposals will be elaborated from the following aspects.

Geological Protection

Geoparks are areas which provide an integrated protection and sustainable development of geological heritage (Wang et al. 2015a, b). When a geopark is being formed, it should educate people about geology and environment, the establishment of sustainable development, and safeguarding of a geological inheritance for future generations (Yilmaz 2002; Citiroglu et al. 2017). Weathering, erosion, and natural disasters have strong influences on the protection of natural resources. Due to weathering along their joint fissures, some outcrops have already undergone erosion, and rockfalls can occur at any time. Necessary protection measures (Han et al. 2018) have already been implemented in the geopark, especially for geoheritage with global significance. For example, the Xiaotianmen fissure has been reinforced with steel brackets. To address rockfalls, protective screening has been installed in the oval pit of kimberlite. CCTVs provide real-time monitoring of all geoheritage with global significance (Fig. 9).

Yimengshan Geopark can learn from the mission of the National Park Service (USA): *to protect the landscape, natural and historical sites, and wild animals; provide people with pleasure without doing harm to the*

Fig. 8 Number of visitors and tourism income of Yimengshan Geopark from 2013 to 2017



environment; benefit future generations (Zhu et al. 2013). The idea of national parks in the USA was created to protect natural wonders of geological interest (Kennedy 1994; James-Williamson et al. 2017).

Infrastructure facilities are a necessary element for tourism development because they can promote the comparative and competitive advantages of destinations (Crouch and Ritchie 1999). The construction of dynamic voice systems, forest fire stations, and protection fences has achieved positive results. To allow tourists to become closer to nature, more wooden plankways need to be built. It is useful to promote free public transportation, which can protect the environment, attract people, and reduce pollution (Avelar et al. 2018). The main area of the park must feature free WIFI and dynamic video interpretations. It has been suggested that a QR code can be added to the bottom of each signboard to allow tourists to obtain more information by scanning it.

Furthermore, it is not sufficient to establish signboards only in the geopark; they also need to be established in every corner of the community to remain fresh in residents’ minds.

Geotourism

Enhancing the experiential products of geotourism (Dowling 2011), such as hiking, horseback riding, climbing, and camping, is significant for attracting tourists to geoparks. Currently, sightseeing is the primary purpose of visitors at this geopark; nevertheless, this geopark features some tour activities, such as bed and breakfast, outward bound, and chess and

card entertainment. However, these activities cannot stimulate people’s desire for knowledge. As the host, this geopark needs to make thoughtful plans to improve participants’ willingness and desire to know more about the geopark through the popularization of geoscience; therefore, this approach requires the development of popular science tourism.

Education Programs

A geopark is responsible for popularizing geoscience and related knowledge. Strategies for popularizing geoscience (Manuel and Enrique 2017; Mariotto and Venturini 2017; Zangmo et al. 2017) include offering different courses for different grades in school; hiring experts who majored in park management, environmental protection, or geology; inviting villagers who have lived in the area for their entire life; asking scenic spot instructors to improve their interpretation skills; and employing educators to give lessons about the geopark (Liu 2016; Began et al. 2017). During summer vacation, an experience course can be arranged in the geopark, thus providing a few days of camping and fun for students. Yimengshan Geopark should also provide online courses that can be downloaded for free.

It is a good idea to have a tour guide to introduce the geopark at a fixed outdoor site at a fixed time. For example, in popular science educational areas in geoparks, tour guides give a 20-min speech, including 5 min of questions, which covers all appropriate geoscience topics. Visitors need to be motivated and involved in these activities so that they remain



Fig. 9 Geohazard protection. **a** Geohazard surrounded by a fence. **b** Fissures reinforced by anchor and injection. **c** Slope reinforcement

attentive. Only in this way can the interaction between a geopark and tourists increase before the tourists enter the geopark.

Geopark personnel training courses need to be strengthened for tour guides, who need to be fully equipped with knowledge about the geoheritage and flora and fauna resources in the geopark. Tour guides need to understand the types, characteristics, and formation of geoheritage; they need to be familiar with the pictures, specimens, and characters displayed in the museum; they need to improve their ability to provide interpretations to different tourists; and they need to be able to use the museum facilities skillfully so as to guide tourists to allow them to properly participate in experiential activities. Every employee in the park, whether a manager, member of the administrative staff, tour guide, cleaner, or security guard, must possess knowledge of the geopark and be able to interpret it.

A current trend involves building remote learning platforms to train volunteers and improve the skills, knowledge, and interpretation abilities of tour guides. Volunteers receive initial and ongoing training to meet national service standards and to gain sufficient experience and knowledge to build a stable and sustainable development system in a geopark.

As for public science popularization, all descriptions of geological knowledge must be concise and clear to ensure that everyone can understand them. The content of each signboard must have a well-designed layout. It is necessary to guide the audience through a logical reading path (Mariotto and Venturini 2017). Visitors are more likely to read dialogue than the entire text, as the former can help visitors more easily understand scenic spots and geological phenomena and can also help increase the amount that they read. The text should provide simple and easy explanations when popularizing geological knowledge, whether using dynamic explanations, interpretations of static text, or signboards; above all, useless information must be ignored. The combination of analogies and examples from daily life can be used to concisely interpret scientific phenomena. Although some visual elements, such as simple and structural drawings, are not related to geological science, they can be used if they are intensely attractive to visitors.

Sustainable Regional Development

Encouraging community participation is the best way to promote sustainable development. Yimengshan Geopark needs to enhance the community and local residents' understanding of geoheritage, set up signboards on every corner in the community, and use simple language to explain the scientific value of each geoheritage.

The community needs to participate in the development of geoparks by making decisions, investigating and evaluating resources, setting development goals and strategies (Károly

and Mohammed 2017), and running businesses related to geotourism (Suzuki and Takagi 2018) products and tourism. Local residents are also needed to help professionals carry out geological surveys and to participate in their evaluation. For example, Yimengshan Geopark can follow the model of America's national parks (Zhu et al. 2013) when installing interpretation media; in this model, planning centers, national parks, engineering companies, and park managers maintain constant communication, but the owner also listens to the relevant suggestions and evaluations of the park staff and visitors.

To build a community participation model (Popa et al. 2017) protected by regulations and policies, it is necessary to fully consider the economic interests and development of the community (Avelar et al. 2018; Melinte-Dobrinescu et al. 2017).

- 1) Encourage residents to participate in the management or staffing of the geopark.
- 2) Encourage residents to sell geotourism products, especially handmade articles.
- 3) Encourage residents to run businesses in geoparks, such as AirB&Bs.
- 4) Enhance cooperation between enterprises and geoparks for mutual benefit to increase the geopark's visibility.
- 5) Reference an effective profit distribution model to ensure the improvement of residents' income.
- 6) Attract the supervision and involvement of civil society and individuals.

Only in this way can Yimengshan Geopark integrate social resources; absorb funds, technologies, and human resources from all parts of society to reduce the government's burden; fully stimulate residents' motivation by arousing public concern and participation; stimulate local employment; and promote sustainable development and eventually attract tourists.

Conclusion

This paper has laid a foundation for the development of geotourism by analyzing and describing the types of geoheritage in Yimengshan Geopark. SWOT analysis confirms the possibility of the sustainable development of Yimengshan Geopark. Ideally, the adoption and utilization of geoheritage protection and the tailoring of scientific popularization activities for a targeted audience in Yimengshan Geopark can be used as a reference and model for other geoparks.

When protecting geoheritage, due to the large area and large population of the geopark, some geoheritages will inevitably be located in the community. With the development of geotourism in recent years, although most of them have

improved, some local residents are not sufficiently aware of the need for the protection of geoheritage. Thus, we must find a better way to accomplish this. At present, the descriptions of some geoheritage sites are not easy to understand, and we still have more work to do before achieving our goal of “we hope that all descriptions can make pupils understand.” Increasing numbers of visitors are focusing on the scientific meaning behind the scenery rather than on the scenery itself. Thus, we need to push our educational programs to “be good story tellers during interpretation.” The ultimate aim of Global Geoparks is to provide new opportunities for the development of the local economy and to benefit the local people. We are considering referring to foreign geoparks’ council system and building the first domestic community participation system, i.e., the *Yimengshan Geopark Council*. Currently, we are preparing regulations and rules. The establishment of this system can provide a reference for China’s geoparks. We need to reference this method at home and abroad to improve tourists’ participation due to the limitations of different types of geotourism activities.

Overall, Yimengshan Geopark needs to make a strong effort to become a member of the UNESCO Global Geopark Network.

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