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The socio-economic benefits of establishing National Geoparks in China

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Since 2000, based on a wealth of geological heritage sites and experience with their conservation, China has formally approved the establishment of forty four National Geoparks, whose distribution and characteristics are dominated by structural setting and neotectonism. Conserving and developing the sites have brought about favorable social, economic and environmental benefits, and created a positive climate for their inclusion in the world Geopark network under the patronage of UNESCO.

Geological sites record the important physical phenomena from which we can trace the evolutionary history of the Earth. They serve as an avenue for the understanding of the Earth's 4,600 Ma-history, and are the only source providing essential information on the Earth's evolutionary changes and processes. In this connection, people regard geological sites as an invaluable legacy bestowed by Mother Earth and name them a 'geological heritage'. Safeguarding and treasuring this heritage, which, once lost can never be recovered, has become a matter of common concern for the people of the global village.

The history of the study and conservation of geological remains can be traced back to ancient times. But because of underdevelopment of science and technology, no scientific answers were available then to the mysteries hidden within these phenomena, and the conservation efforts were spontaneous. Scientific research on geological remains and the progressive recognition of their significance are in a real sense the outcome of the Industrial Revolution and the development of modern science. From ignorance to science, and from spontaneity to consciousness, there is an endless progression.

The establishment of Geoparks in China

From geosites conservation to the setting up of Geoparks, China has kept close collaboration with UNESCO's Division of Earth Sciences and the International Union of Geological Sciences (IUGS), making contributions to the worldwide promotion of Geoparks and standing in the forefront worldwide.

In June 2002, the IUGS invited China, as a sponsor country, to propose to the UN an International Year of Planet Earth. In his letter to the Chinese National Committee, Dr. de Mulder stated: "This conclusion is based, among other items, on the presentation given by the Minister of Land and Resources in Rio de Janeiro, also by Song Ruixiang, and the new initiative on Geoparks, and on the continuous support of your country to the IUGS Journal *Episodes*. To my opinion the current position of China in the Geosciences on a world-wide scale, fully merit such a leading role."

More and more importance has been attached to the conservation of geosites and the establishment of Geoparks following the recent International Geological Congresses. The 30th IGC held in Beijing, China organized a special symposium, titled, 'Geological Sites for the World Heritage List', which promoted the establishment of Geoparks

in European countries. During the 31st IGC in Rio de Janeiro, Brazil there was a symposium on Geosites, which raised the awareness of many countries. After the 31st IGC, China, Germany, Switzerland and Austria set about the construction of national geoparks, gradually forming a global network. During the 32nd IGC, to be convened in Florence, Italy in August 2004, two Topical Symposia (T16 and T17) will be related to cultural heritage and to geosites, geoparks, and geotourism, respectively; and the theme of the Special Symposium S03 will be 'Cultural heritage: International approaches and perspectives'.

To enhance the protection of world geological heritage, propel geoscientific popularization, increase the public appreciation of scientific knowledge, seek new growth points for economic development, and create employment opportunities for local residents, UNESCO took the initiative to 'promote a global network of geosites having special geological features' at its General Conference in 1997. At the 156th session of UNESCO's Executive Board in 1999, it was further clarified that a UNESCO Geopark 'comprises a number of geological heritage sites of special scientific importance, rarity or beauty; it may not be solely of geological significance but also of archaeological, ecological, historical or cultural value.' Pursuant to a decision by its Executive Board in June 2001 (161EX/Dicisions 3.3.1), UNESCO was invited to support ad hoc initiatives of member states to promote territories or natural parks having special features (so-called geoparks).

Early in 1985, Chinese geologists proposed to establish geoparks in geologically significant territories with beautiful geological landscapes, in order to enhance their conservation and gear up geoscientific surveys. In July 1987, the former Ministry of Geology and Mineral Resources (MGMR) issued the "Circular on Establishing Geological Natural Reserves (proposed)"; and for the first time the conservation of geosites was proposed in the form of ministerial regulations. In May 1995, the MGMR promulgated the "Regulations for the Protection and Management of Geosites", in which the establishment of geoparks is regarded as a tool for protecting such sites. In December 1999, the establishment of geoparks was further promoted at the National Geology-Geomorphology Protection Conference held by the Ministry of Land and Resources (MLR) in Weihai, Shandong. On April 3, 2000, the ministry approved a report made by the Department of the Geological Environment on the launching of geoparks. In August the same year, the "Circular on the Leading Organization and Staffing of National Geosites (Geoparks)" was issued; at the same time, the Review Committee of National Geosites (Geoparks) was formed. In September 2000, the MLR issued the "Circular on the Nomination of National Geoparks", with the "National Geopark Nomination Form", "Outlines of a Report on the Integrated Investigation of National Geoparks", "Guidelines for the Overall Planning of National Geoparks (proposed)", "Organization and Working Regulations of the Review Committee of National Geosites (Geoparks)", and "Review Standards for National Geoparks" attached. These have brought the establishment and management of China's National Geoparks into the orbit of legislation and healthy development.

Since 2000, provinces, autonomous regions and municipalities of China have recommended quite a number of geological heritage sites, and applied for their designation as National Geoparks. Through strict review and appraisal, forty four National Geoparks have been approved in two batches so far (Table 1).

Table 1 Classification and features of major geoheritage sites of National Geoparks of China.

Category	Representative National Geopark	Major features of geoheritage	Controlling geological setting	Relevant natural conditions	Representative major humanistic characteristics
Stratigraphic heritage	9. Fuping in Hebei	Type section of Achaean Longquanguan Formation.	Pediment fault system of Taihang Mountains, fault-block mountain masses.	Waterfalls, hot springs.	Early-stage activities of Chinese geologists.
	18. Songshan in Henan	Three distinct unconformity interfaces from the 3.5 Ga-Achaean Era to the Proterozoic / Mid-Proterozoic and Paleozoic / Upper Paleozoic; naming place of three major tectonic movements.	Differential elevation generated by block movement on the North China Platform.	Precipices, perilous peaks, dense forests.	Shaolin Temple; Songyang Academy of Classical Learning; tower forest.
	5. Jixian in Tianjin	Mid-Upper Proterozoic stratigraphic section (1.8-0.8 Ga), rich fossils, macroscopic algae earlier than 1.7 Ga.	Gently occurring old stratigraphic section on the North China Platform.	Carbonate peak cluster landform.	Huangya Pass, important ancient battlefields.
	4. Qinhuangdao in Hebei	A complete stratigraphic section in northern China; marine-erosion landform; granite peak hills.	Territories affected by the tectonomagmatic belt of Yanshan movement on the northern edge of the North China Platform.	Yanshan Mountains and coastal hills; sandy beaches; red-forest-covered low hills.	Starting point of the Great Wall; famous summer resort.
	24. Changshan in Zhejiang	Ordovician Darriwilian GSSP; reef limestone; karst.	Stable carbonate neritic deposits on the Yangtze Platform.	Karst hills.	Close to the Taihu Lake scenic spots.
	13. Luochuan in Shaanxi	Type section of loess deposits in China; loess landforms.	Loess deposition area in western North China Platform.	Loess gullies, plateaus, hills and ridges; sparse dry-land vegetation.	Loess folk customs and culture; venue of Luochuan Conference in the history of the Chinese Communist Party.
Paleontological heritage	42. Chengjiang in Yunnan	Early Cambrian (0.53 Ga) explosive biomultiplication, synchronous emergence of tens of biologic groups and species.	Stable neritic environment.	Hills, lakes (rift lakes).	Fuxianhu lake sceneries.
	20. Huainan in Anhui	Huainan biotic community (0.7-0.8 Ga); late to early Cambrian stratigraphic sections.	Southern edge of North China Platform, close to Yangtze Platform.	Juncture of the north and south climatic zones of China.	Ancient field of Feishui battle in Chinese history; ancient city of Shouzhou.
	36. Anxian in Sichuan	Bioherms produced by stretches of siliceous sponge; karst landforms.	Western edge of Yangtze Platform.	Longmenshan moderate- to-low hills; forests.	Ancient temples, fortified villages, strongholds.
	38. Zigong in Sichuan	Burial place of many kinds of dinosaur fossils; complete fossil skeletons; dinosaur dung.	Yangtze Platform; Mesozoic inland lakes.	Central Sichuan red bed hills.	Provincial guilds; ancient salt wells over 1,000 m in depth.
	15. Liujiaxia in Gansu	Dinosaur footprints, the largest being over 1 m in diameter.	Mesozoic inland lakes in western North China Platform.	Valleys in the upper reaches of the Yellow River.	Liujiaxia power station and reservoir.
	6. Yanqing in Beijing	Silicified wood buried in situ in groups.	Northern edge of North China Platform; Mesozoic inland basin brought about by Yanshan tectonic belt.	Moderate-to-low mountains.	A large amount of humanistic relics; ancient rock dwellings.
	1. Jiayin in Heilongjiang	Dinosaur fossils; the first dinosaur fossil unearthed in China, being also the one of terminal Cretaceous in China; angiosperm fossils.	Wandashan massif.	Natural landscape of northernmost China.	Sanjiang recreational area in Northeast China.
	10. Shanwang in Shandong	Rich and well preserved Mesozoic fossils of ten-odd kinds and 600-odd species of fish, reptiles, amphibian, mammal, and insects, plants.	Volcanic fault basins.	Volcanic cones, craters, crater lakes.	Museums.
Structural geological heritage	19. Baotianman in Henan	Traces of tectonic and metamorphic processes.	Central (Qinling) orogenic belt of continental China.	Biodiversity at the juncture of the north and south climatic zones in China; thick vegetation.	Nature reserves.
	37. Longmenshan in Sichuan	Long-range nappe structures (Longmenshan tectonic belt).	Juncture of Qinghai-Tibet Plateau and the western margin of Yangtze Platform.	Zhongshan forest.	Ancient temples, fortified villages, strongholds, caves.

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Category	Representative National Geopark	Major features of geoheritage	Controlling geological setting	Relevant natural conditions	Representative major humanistic characteristics
Geologic-geomorphic heritage <i>Danxia landscape</i>	34. Renhua in Guangdong	Place where the Danxia landscape was named. Typical and representative Danxia landscape.	Fault-depression basin on the South China paraplatform.	Beautiful hills and waters, thick vegetation.	Inscriptions on precipices.
	29. Longhushan in Jiangxi	Danxia landscape, peculiarly shaped rocks.	Fault-depression basin on the South China paraplatform.	Beautiful hills and waters.	Inscriptions on precipices; suspended coffins; birthplace of Taoism.
	31. Chenzhou in Hunan	Danxia landscape, caves, gorges, natural arches, cliffs.	Fault-depression basin on the South China paraplatform.	Low hills.	Temples; ancient stone tablets; suspended coffins.
	32. Langshan in Hunan	Danxia landscape, mesas, peak columns, crevices, cliffs.	Fault-depression basin on the South China paraplatform.	Zijiang River valley.	Tombs of ancient celebrities; ancient battlefield.
	33. Zijiang in Guangxi	Danxia landscape, mesas, peak columns, steep precipices and cliffs.	Fault-depression basin on the South China paraplatform.	Upper reaches of Zijiang River; beautiful waters and dense forests.	Local customs and practices of Miao minority.
	26 Taining in Fujian	Lakeside Danxia landscape, reflection of peak columns and steep cliffs in lake, peculiarly shaped rocks of red sandstone.	Fault-depression basin on the South China paraplatform.	Curiously shaped peaks and rocks scattered in and near the Jinhu Lake, beautiful waters and dense forests.	Local customs and practices of Yu minority; home of poetry; ancient tombs and houses.
	23. Qiyunshan in Anhui	Danxia landscape: red cliff, long wall, flat cave, mesa, valley, lane; dinosaur fossils.	Fault-controlled Mesozoic volcano-sedimentary basin on the northern edge of the South China paraplatform.	Low hills covered with thick woods.	Numerous inscriptions on precipices; Taoist culture; fortified villages.
<i>Yadang landscape</i>	16. Dunhuang in Gansu	Wind erosion has carved out a curiously shaped landscape from loosely cemented mid-Oligocene river and lake deposits; during the night the wind howls like thousands of monsters.	River and lake deposits in the Cenozoic fault depression basin northeast of Tarim massif.	Desert landscape, stretches of black desert lacquer.	Mogao Grotto in Dunhuang, a grotto with richest cultural relics preserved in China.
<i>Carbonate karst caves</i>	7. Shihuadong in Beijing	Limestone karst caves of seven layers; peculiarly shaped stalactites, stalagmites, rock columns and flowers; underground streams in two lowermost layers.	North China platform repeatedly block-uplifted and eroded in neotectonic movements.	Low hills and valleys; karst areas.	Temples; ancient architectures; and many other relic sites.
	11. Xiong'ershan in Shandong	An animal-shaped karst rock mountain thrusts itself high over the hills; peculiar gorges and grotesque cave stones.	Formed through differential elevation and subsidence of carbonate rocks due to Cenozoic fault dissection on the North China platform.	Low hills; typical karst landforms in North China.	Fallow lands.
<i>Carbonate rock peak forest landscape</i>	41. Shilin in Yunnan	Karst landforms, sword-like stone forest, 20-50 m high peak clusters, well-developed caves and waterfalls.	Repeated post-Permian differential elevation and subsidence on the southwestern edge of Yangtze platform; water-soluble erosion.	Hills and peak-forest plain.	Local customs and practices of Sani minority; relics of ancient human activities.
	8. Laiyuan in Hebei	Dolomite peak forests, peak columns, precipices, springs; source of Laishui River.	North China platform; block differential elevation and subsidence of Cenozoic era; vertical faulting; well-developed joints; collapses; frost splitting.	Moderate-to-low hills; beautiful hills and waters; inexhaustible springs.	The Great Wall, ancient mountain passes and temples.
<i>Quartzose sandstone peak forest landscape</i>	30. Zhangjiajie in Hunan	Quartzose sandstone peak forest; 3,000 and more peak columns, the highest reaching 400 m; nearby carbonate karst caves.	South China paraplatform; three groups of Cenozoic faults intersecting the horizontally lying quartzose beds; collapse; scouring.	Moderate hills; beautiful hills and waters; pines on the peak columns like a miniature of trees and rockery.	Local customs and practices of Tujia minority.
<i>Granite peak forest landscape</i>	22. Huangshan in Anhui	Granite peak forests, rock columns, peculiar peaks and grotesque rocks, deep and secluded valleys, hot springs.	South China paraplatform; faulting activities and differential elevation and subsidence of Cenozoic era; running water action and glaciation.	Moderate hills with pine trees everywhere; thick woods.	Cultural relics left over by men of literature and writing; ancient houses.

(continued)

Category	Representative National Geopark	Major features of geoheritage	Controlling geological setting	Relevant natural conditions	Representative major humanistic characteristics
	3. Hexigten in Inner Mongolia	Columnar peaks resembling human beings, animals or castles, produced by granites with well-developed horizontal joints as a result of frost splitting, freeze-and-thaw action and wind erosion.	Juncture of Xingmeng geosyncline fault belt and Yanshan tectono-magmatic belt on the northern edge of the North China platform.	Juncture of Da Hinggan Ling primeval forest, Hunshandake Desert, and Horqin Desert.	Cultural relics of the Liao and Jin dynasties; rock wall paintings.
Glacial geologic heritage <i>Fossil glacier</i>	28. Lushan in Jiangxi	Birthplace of Quaternary glaciological research in China; complete sections; glacial remnants and their naming places; old stratigraphic sections of southern China; fault-block mountains.	Old continental nucleus of the South China paraplatform; differential elevation and subsidence in the fault-block movement of Cenozoic.	The Lushan Mountain, the Boyang Lake, and the Yangtze River enhancing each other's beauty; thick woods.	Ancient academy of classical learning; inscriptions on precipices; temples; buildings of various styles of the world.
<i>Modern glacier</i>	39. Hailuoguo in Sichuan	A 29-km long modern glacier on the east of the Gongga Mountains, the lowermost ice tongue going down to 2,750 m a.s.l.; hot springs	Juncture of the western edge of the Yangtze platform and the folded belt of the Kangdian Hengduan Mountains, strongly uplifted in Cenozoic.	Coexistence of vast primeval forest, glacier and spring.	Culture of the Zang minority; Moxi ancient town.
Volcanological heritage	2. Wudalianchi in Heilongjiang	Volcanic landforms; 14 volcanoes, erupted from Tertiary to Quaternary with the latest eruption in 1721; typical morphological features of edifice, volcanic lake and lava.	Effects of Circum-Pacific tectonic activities; East Asian rift series.	Plains, hills, well-developed vegetation.	Ancient temple; ore sludge; medicine spring.
	27. Zhangzhou in Fujian	Littoral volcanic rocks; basaltic prismatic joints; volcanic vents and cones; marine erosion landform.	Effects of Circum-Pacific tectonic activities; East Asian rift series.	Coastal hills, sand beaches, islands.	Ancient battery; castle; temple; recreational sites.
	43. Tengchong in Yunnan	Modern volcanic landform; geothermal springs; biodiversity; various hot springs; sinter.	Folded belt of Kangdian Hengduan Mountains; intense neotectonism.	Low hills; spring lakes; thick vegetation.	Ancient border city; customs and practices of ethnic minorities.
	35. Huguangyan in Guangdong	Volcanic landscape; Ma'er Lake.	Circum-Pacific volcanic rocks.	Hills; thick vegetation; lakes.	Temples; inscriptions on precipices.
	21. Fushan in Anhui	Caves created by weathering of volcanic rocks; complete volcanic mechanism; volcanic cone; crater; cinder; lava flow.	Fault depression basin of East Asian rift valley series.	Hills; thick woods.	Temples; inscriptions on precipices.
	25. Linghai in Zhejiang	Late Cretaceous volcanic rocks; volcanic landform; columnar joints; pterosaur and bird fossils.	Circum-Pacific tectono-volcanic rock belt.	Coastal hills.	Ancient architecture.
Hydrological heritage	12. Hukou waterfalls on the Yellow River	The greatest waterfall on the mainstream of the Yellow River; narrow and deep gorges; retrogressive erosion.	North China platform; a series of joints formed by the influence of the Indo-Sinian movement, which controlled the erosion of the river.	Yellow River valley; incision.	Inscriptions of ancient poems; relic sites of World War II.
	17. Yuntaishan in Henan	Piedmont fault of the Taihang Mountains has created long walls, red cliffs, narrow gorges, lane-like valleys, urn-like valleys; many waterfalls, of which the Tianpo waterfall being 304 m in height.	North China platform; differential elevation and subsidence of the piedmont fault of the Taihang Mountains.	Moderate Mountains; gorge landform; dense forest.	Temples and towers; ancient trees; place where the seven ancient Zhulin scholars lived in seclusion.
Engineering geological heritage	40. Daduhe valleys in Sichuan	Dadu River valley and narrow gorges and lane-like valleys of its tributaries; Dawa Mountain and Quaternary glacier; formidable huge project of Cheng-Kun Railway cutting through the valleys with bridges linking to culverts and caves to tunnels.	Western edge of Yangtze platform; N-S trending Chuandian structural belt; intense effects of neotectonism.	Moderate and low mountains; deep valleys and dense forest.	Customs and practices of Zang and Yi minorities; Cheng-Kun Railway project.
Geohazard heritage <i>Large-scale mountain mass slide induced by collapse earthquake</i>	14. Cuihuashan in Shaanxi	Earthquake-induced mountain collapse and accumulation, which dammed the river valley to create a lake.	Piedmont faulting on the north of Qinling Mountains.	Moderate mountains; talus of boulder gravel.	Inscriptions on precipices by ancient celebrities.
	44. Yigong in Tibet	Modern glacier; high mountain and deep valley; large-scale mountain mass slide; vertical zoning of vegetation.	Uplifted belt of Qinghai-Tibet Plateau.	High mountain; deep valley; modern glacier.	

The socio-economic benefits of establishing Geoparks in China

It has been centuries since our ancestors realized and enjoyed geotourism resources. In their masterpieces through the ages, many poets and writers have sung the praises of renowned mountains and great rivers, and their audiences can feel poetry in the painting and painting in the poetry. Some monks and travelers, being free from worldly cares, abandoned themselves to the mountains and rivers, spurred by the theory that man is an integral part of Nature. The 5,000-year long Chinese history is also the history of natural resources exploration and protection. The recognition, exploration and protection of geotourism resources are integrated smoothly in the nation's development. They have provided a broad material basis for the advance of the national culture, and the latter in turn has added value to the cultural connotation of the resources. The perfect harmony of the rich and colorful geotourism resources with the long history and civilization of China is the major characteristic of Chinese National Geoparks, and also an important factor for China to take the lead in promoting the UNESCO-sponsored Geopark Programme at the state level.

The 44 national Geoparks are located in territories with relatively focused geological heritage sites. The approval of National Geoparks has stimulated provincial and municipal governments to attach greater importance to the protection of China's geological heritage. Many local governments have reviewed and approved local geoparks at the relevant levels. As a result, a network of geological heritage protection, with National Geoparks as the core, has begun to emerge in China. Geoparks have become a new growth point of local economies, and created a new field of employment. In return, geological popularization is well implemented; geoenvironmental protection has begun to win support among local people; active academic exchanges in this aspect have led to the establishment of many thematic research centers; and the scientific-technological connotation of tourism has increased.

Strengthening ties and cooperation with foreign geoscientists

Exchanges and co-operation between Chinese and foreign geologists have been centered mainly on scientific research, with a few on putting geoscience to the service of the social economy. However, in geoheritage protection we have developed a new field of cooperation.

China is among the countries that have actively joined the promotion of the UNESCO-sponsored 'Geopark Programme'. Prof. Zhao Xun, first author of this paper, took part in the feasibility study of the Programme organized by UNESCO. At the 2002 IGCP EC meeting in Paris, China's presentation based on its 44 National Geoparks already approved was warmly welcomed. It was generally acknowledged at the meeting that China had given a great impetus to the Programme. Even those who had dissented from the Programme commended China as saying, 'In developing countries, setting up Geoparks is a feasible way to protect the geoheritage.'

In the new field of the promotion of National Geoparks, geoscientists at home and abroad collaborate closely, aiming at a common goal of global sustainable development.

Increasing scientific content in the tourism industry

UNESCO has requested that geoparks should serve as a base for scientific popularization. In this connection, we have launched an all-round improvement in tourism information, the erection of sign posts, tourism route design, guide book compilation and tour guide training, as well as in the furnishing of museums. Knowledge of earth sciences, meteorology, zoology and botany has been injected in information to replace fairy tales and folklore. Scientific popularization has been integrated with tourism, and education with recreation. So far, 33 of the 44 National Geoparks have completed the improvement. Today

Geoparks widespread in the country have become bases of scientific popularization for the general public.

Geoheritage and geoenvironmental protection becoming common knowledge

Geosites are records of geological history handed down for tens and thousands of millions of years, whereas the history of mankind is merely millions of years and mankind's recorded history is only thousands of years. To understand the present status of the planet Earth on which we are living, the study of the phenomena and records that have preserved through different geological processes is indispensable. Only in this way can we predict the evolutionary trend of the Earth, work out pertinent measures and take precautions in order to achieve a harmonized co-existence between heaven, earth and man, and to bring about sustainable development. The establishment of geoparks has helped local governments and inhabitants become aware of the importance of safeguarding geoheritage resources and the geoenvironment, and conscientiously take part in the campaign. As a result, a new social mode of cherishing the geoheritage and geological environment is being cultivated. For instance, people living in the area of the Yuntaishan National Geopark, Henan Province, are taking great care of the woods and no one is allowed to fell trees there. Following their example, protecting natural resources and the geological environment has become a common practice among residents of the surrounding areas.

Enhancing the local economy and employment

By virtue of geosites and favorable geoenvironment, local governments have regarded geotourism as a new economic growth point which can alleviate the expense of geoheritage preservation, increase local revenues and enhance employment. Take again as an example the Yuntai National Geopark in Henan. This Geopark, approved in 2001, covers an area of 190 sq km and is characterized by a combination of 'cliff-valley-forest-waterfall'. With the addition of scientific and cultural content to tourism, it has become a provincial base for science promotion and education, and attracted a great many young students as well as leading scholars. In 2001, the number of visitors reached 600,000, and the income from admission fees amounted to 14 million yuan, twice the average of the previous years. In 2002, the number of visitors soared to 940,000, and the income from admission fees swelled to 27.2 million yuan, up 68% and 97%, respectively, compared with the previous year. Tourism spurred tertiary industry and enhanced local employment. In 2002, the revenues from tertiary industry increased to 620 million yuan, 15% over the previous year. More than 60 hotels were newly built in the county, and about 4,000 jobs were offered by tourism development. Meanwhile, the county attracted investment from domestic and foreign enterprises. The projects under construction or negotiation in this aspect totaled 379 million yuan-worth.

Another example is the Jinhu National Geopark in Taining County, Fujian Province, constructed in 2000 and characterized by 'waterside Danxia landscape'. The related tourism projects attract a great number of visitors. In 2001, the total revenues from tourism reached 202 million yuan, 35.7% over the previous year, accounting for 13.5% of the county's GDP. Revenues from tourism-related tertiary industry increased to 450 million yuan, up 12.3% compared with the previous year and accounting for nearly 30% of the county's GDP. Thus, tourism has become a pillar industry of the county. It has brought along such trades as catering, transportation and cultural recreation, furnishing employment for about 2,800 people. Particularly noteworthy is the resolution of the migration problem caused by the construction of the Jinhu Reservoir, which was a hard nut to crack for the county authorities. The establishment of the geopark and the speedy development of the geotourism industry has created jobs for a great many displaced people, who are now paid three to five times greater than before. As a consequence, the instability factor has been eliminated, and people are making a good living there.

Local people of all walks of life as well as local authorities have clearly realized that the construction of geoparks can not only preserve the geological heritage, optimize the geological environment, promote the popularization of science, and add a scientific content to tourism, but are also beneficial to the local economy and employment. It is a concrete task for geology to serve the sustainable development of the social economy, and an undertaking that has enjoyed immense popular support.

Geoscientific significance of China's National Geoparks

Geological and geomorphologic landscapes in China feature numerous mountains and rivers. The 44 National Geoparks have rich geoscientific connotations. Some are renowned as the localities of rare fossils, and others for global boundary stratotype section and points (GSSPs), for significant aspects of tectonic evolution, for grotesque and attractive relief, for volcanic wonders, for vestiges of glaciation, for seismic grandeur, or for supergenetic mysteries. All these sites are products of long-standing geological processes, reflecting the closely related geological setting.

The geological setting of Chinese geoscientific landscape resources

Physiographic features are the basic reflection of structural patterns, while the latter control the development of the former. Modern physiographic features of China embody a concentrated expression of

the geological structures that experienced synthetic actions from both internal and external agencies during the long geological processes (Cheng Yuqi, 1994). Continental China was pieced together through these processes from several relatively long-stable landmasses and the important mobile belts distributed within them. Modern physiographic patterns are characterized by 'the step-like relief high in the west and low in the east, and the regular-spread mobile fault structural belts' (Ye Dingheng et al., 1998). The three tectono-geomorphic steps of China demonstrate regional differences in crustal movement and geotectonics (Environmental Geology Institute of the Ministry of Geology and Mineral Resources, 1991; Cheng Yuqi et al., 1994). According to Wu Zhenhan (2001), from west to east, the relief in China declines stepwise, giving rise to three tectono-geomorphic steps and four tectono-topographical terraces. The results are summarized below, from west to east (Figure 1).

The Qinghai-Tibet Plateau is the highest-level topographic terrace in China, confined by mountain ranges like the Pamirs, the Altun, the Qilian, the Hengduan and the Himalayas. The altitude is 3,000 m to 4,000 m a.s.l., reaching over 5,000 m in northern Tibet. The plateau is relatively flat at the top, high in the west and low in the east, forming 'the roof of the world'. This is the place where the major rivers of Asia originate. The Hengduan Mountains to the east rose quickly in Cenozoic and were incised strongly by the Jinsha, Nujiang, and Lancang Rivers, bringing forth high mountains and deep valleys with the relative altitude difference reaching over 3,000 m. This is the first step in China's topography.

The second-level terrace encompasses northern and eastern Tibet, consisting of secondary plateaus like the Alxa, Inner Mongolia, Loess, and Yunnan-Guizhou, accompanied by basins (e.g. Hexi Corridor, Tarim and Sichuan basins) and mountains built up by neotect-

Figure 1 Sketch map of locations of National Geoparks in China.

tonic movements (e.g. Tianshan, Qinling, and Yinshan ranges). The Da Hingganling-Taihang-Xuefeng Mountains form the eastern border, reaching 1,000 to 2,000 m a.s.l. This is the second step in China's topography.

On the third-level terrace, the vast hilly plain and low mountain areas in eastern China are 500–1,000 a.s.l., while the Northeast China plain, the North China plain and the plain on the middle and lower reaches of the Yangtze River are all below 200 m a.s.l. In the east there are volcanic rocks distributed intermittently along the coast and the middle-to-low mountains formed by uplifted blocks. These constitute the third step in China's topography.

The fourth terrace consists of the gentle continental shelves of the Yellow Sea, the East China Sea and the South China Sea, as well as the adjacent littoral plain areas, being the natural extension of continental China, with slope angle less than 1°. On the terrace there are deltas of the Yellow, Yangtze and Pearl rivers, a crisscrossing network of rivers and scattered paleolacustrine bogs.

The creation of the overall features of the three steps and four terraces is controlled by the Earth's unified dynamic mechanism with driving forces coming from the relative movement, compression, subduction and sliding of the Eurasian, Indian, Pacific and Philippine plates. The variation of gravity and magnetic fields and, in particular, the abrupt changes of the geophysical fields, as well as the depth migrations of Moho, are in good agreement with geothermal gradients, showing the geodynamic basis of the regularity of subsurface topographic changes. Zhu Xia et al. (1990) pointed out: 'Matching the northward movement of the Pacific plate, the compressions of continental blocks are consistent with the NNE-striking, dominantly left-hand translational movements; and the similarly striking volcanic rock belt of Late Jurassic-Early Cretaceous can be related to crustal melting occurred under strong shearing. These combined to create the network pattern composed of the inherited NNE- and NWW-striking movements started in Late Jurassic and continued in the Cretaceous up to the Tertiary.'

Classification of Chinese National Geoparks and their geological setting

The distribution and classification of Chinese National Geoparks have a close relationship to the geological setting and geomorphic features. Nowadays, with different focuses of attention of the author, the criteria of classification are different. The Operational Guidelines of the network of Geoparks under UNESCO'S patronage place particular emphasis on geoheritage-related disciplines. There are large-scale geoheritage sites of economic geology and mining relics, engineering geology, history of the Earth, geomorphology, glacial geology, hydrogeology, mineralogy, paleontology, petrography, sedimentology, soil sciences, stratigraphy, structural geology, and volcanology. Many Chinese geologists have proposed classifications of geotourism resources (Tao Kuiyuan et al., 2000; Chen Anze et al., 1991). These are virtually the same, placing stress mostly on the subjects and the major geological agents concerned.

Based on a synthetical analysis of the 44 National Geoparks already established, the geological heritage sites are classified in the following categories: stratigraphic heritage, paleontological heritage, structural-geological heritage, geologic-geomorphic heritage (sub-classified to Danxia landscape, Yadang landscape, carbonate karst caves, carbonate rock peak forest landscape, quartzose sandstone peak forest landscape, granite peak forest landscape), glacial geologic heritage, volcanological heritage, hydrogeological heritage, engineering geological heritage, and geohazard heritage (earthquake-induced collapse and landslide). These categories can be further subdivided.

The controlling factors in relation to the genesis of the areas where the National Geoparks are located can be analyzed as follows:

1. The geoparks are relatively concentrated in the three topographic step areas.

In the first step area, there is Liujiaxia in Yongjing County in Gansu Province; Longmenshan in Sichuan Province; Anxian in Sichuan Province; Daduhe Valley in Sichuan Province, Hailuoguo in Sichuan Province, and Tengchong in Yunnan Province.

In the second step area, there is Hexigten in Inner Mongolia, Yanqing in Beijing, Baishishan in Hebei Province's Laiyuan County in, Tianshengqiao in Hebei Province's Fuping County, Yuntaishan in Henan Province's Xiuwu County, Baotianman in Henan Province's Xixiang County, Hukou Waterfall on the Yellow River, and Zhangjiajie in Hunan Province.

In the third step area, there is Qinhuangdao in Hebei Province, Linghai in Zhejiang Province, Zhangzhou in Fujian Province and Huguangyan in Guangdong Province.

The above three topographic step areas have unique features of intense tectonic processes and varied landforms. For example, in the magnificent Circum-Pacific volcanic belt of the third step area, each sector has its own charming scenery of lofty mountains or towering crags. Having undergone strong differential elevation and subsidence of pediment faults, the grand Taihang and Wuling mountains of the second step area boast impressive red cliffs and waterfalls. In the first step area there occur the huge nappes of the Longmen Mountains, the surging waves in the Dadu Valley, and the gushing hot springs in Tengchong. Meanwhile, along these step areas differential crustal movements have unraveled quite a few of mysteries concerning the evolutionary history of the Earth's crust. For example, in Baotianman, Baishishan, Yuntaishan and Tianshengqiao many invaluable records displaying the crust's early evolution have been elevated to the surface, and are regarded as 'textbooks of geological history'; in Zhangjiajie and Hexigten, active geological structures have brought great changes to the landscape, displaying the extremely skillful craftsmanship of Nature.

2. The geoparks on the four terraces are partly affected by local faulting.

For instance, the wonderful stone forest in Yunnan, the secluded Lushan Mountains in Jiangxi, the beautiful Huangshan Mountains in Anhui and the precipitous Songshan Mountains in Henan were all created by faulting and differential elevation and subsidence occurring in Mesozoic and Cenozoic times. Intersecting joints provide favorable conditions for river or glacier erosion, giving rise to the mystical stone forest, the towering peaks, the fin-shaped ridges and the deep gullies that offer a wide range of attractions on the vast expanse of the terrace.

In the Yangtze paraplatform of southern China, affected by the activities of the Pacific plate, the NE-NNE-striking faulting has brought about a series of volcanic intracontinental basins since the Mesozoic, which, under dry climatic conditions, created gigantic red sandy conglomerates cemented by calcareous and muddy materials. The red layers, uplifted by subsequent faulting under the influence of the long-range effects of the Himalayan orogenesis of the Cenozoic era, have undergone water erosion and produced many peculiar geomorphic features like mesas, peak forests, peak columns, long precipices, narrow gorges, urn-shaped valley, tunnel-like gorges, rock corridors, flat beds along cliff faces, etc.

As part of the Circum-Pacific belt, the peri-Pacific region in the stable platform area of eastern China has experienced the impacts of four episodes of volcanic activity since the Cenozoic (locally late Mesozoic), bringing forth the 'East Asia continental rift belt' (Liu Jiaqi, 1999). The activity of the fault system led to the upsurge and eruption of magma. 'The orientation of the tectonic line and the volcanic belt are in good agreement with the continental margin. Volcanic activities develop progressively towards the margin.' (Liu Jiaqi, 1999) Among the National Geoparks, Wudalianchi in Heilongjiang Province, Fushan in Anhui Province, Linghai in Zhejiang Province,

Zhangzhou in Fujian Province and Huguangyan in Guangdong Province are typical of the series of volcanoes controlled by different tectonic positions in different phases of the East Asia continental rift belt. The features of the volcanic rocks show clearly the regularity of the changes.

3. In quite a few of the geoparks, the groups of geological heritage sites are not products of a single geological process.

Volcanic eruptions took place four times in the area of the Zhangzhou Volcanic Geopark, forming mutually superimposed volcanic rocks with different tectonic characteristics. The magnificent and lofty columnar joints are found in a specific horizon and position, and the exposure of the fumaroles was caused by long-term marine erosion in the late stage. The rapid differential movements of horst faults in the Lushan area since Cenozoic times has brought about towering block mountains, being an essential factor of glaciation in the Oligocene. The high resistance to weathering of the metamorphic complex was fundamental to the formation of the gorges and precipices. The embryonic form of the stone forest in Yunnan was generated in the late Permian before the eruption of the Emeishan basalts, as evidenced by basalts filled in the paleo-karst caves. Rift-faulting and differential elevation and subsidence in the N-S striking Kang-Dian fracture zone of the Cenozoic era endowed the stone forest with thousands of postures and individuality.

4. Abrupt geological events frequently played a key role in the formation of thrilling geoheritage sites.

According to historical records, the Cuihuashan landslide was created by an intensive earthquake that occurred along the pediment fault of the Qinling Mountains in the 5th year of the reign of Emperor Chengwang of the Zhou Dynasty (c. 11th century to 256 A.D.). Gigantic fallen rocks dammed the river courses, creating lakes, or piled up, forming caves. The Yigong Geopark in Tibet features dammed lakes and varied landslides generated by an extensive landslide in 1999. It has become a favorable base for research into the mechanism of geohazards, and their prediction and prevention. In addition, geoparks in Shanwang, in Shandong Province, Zigong, in Sichuan Province, and other places exhibit group death and burial of ancient living beings. Research findings indicate that volcanic eruptions and environmental pollution might have played an important role in this respect.

Concluding remarks

In their probe into the nature's history, man has come to gradually understand the importance of safeguarding geological heritage; and through long practice of conserving that heritage, we have found an optimal approach for this purpose, i.e., establishing geoparks and making them special landscape areas for protecting the Earth's legacy and the geological-ecological environment. Furthermore, it is important to network them at different levels to form research bases for important geoscientific issues, educational field bases for students, and scientific popularization bases for the general public. In the course of this, the revenues from geotourism, e.g. knowledge tours, science tours and environmental protection tours, can support local economies and promote local employment. These will further sensitize local governments, economic entities and inhabitants to the value of geoheritage conservation. With the creation of the Global Network of Geoparks, it can be foreseen that mankind will, as well as protecting its historical and cultural heritages, open a new page in history in the conservation of geological heritage.

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