On the growth of national geoparks in China: distribution, interpretation, and regional comparison

Guifang Yang  
China University of Geosciences

Zhenghong Chen  
China University of Geosciences Wuhan

Mingzhong Tian  
China University of Geosciences

Fadong Wu  
China University of Geosciences

Robert A. L Wray  
University of Wollongong, rwray@uow.edu.au

See next page for additional authors

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Abstract
Since the year 2000 China has created 139 National Geoparks; it started under the guidance of the former UNESCO’s Division of Earth Science, and has therefore become one of the pioneers in this aspect. Many National Geoparks in China have been described over the past decade, but an understanding of the range of various landform features and their connection with geological and climatic constraints has not previously been published. Based on an increasing awareness of National Geoparks, the aim of this contribution is to provide a comprehensive overview of the National Geoparks of China by reviewing the geological heritage and their intrinsic linkages with geological and climatic controls. A regional comparison of the widespread clastic and karst Geopark landforms indicates that the development of these terrains can only be understood within a synthesis of tectonic constraints, climatic changes and lithological properties, whereas the variety of types, forms, scales and development patterns reflect processes in various climatic settings.

Disciplines
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Authors
Guifang Yang, Zhenghong Chen, Mingzhong Tian, Fadong Wu, Robert A. L. Wray, and Yamin Ping

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by Guifang Yang\textsuperscript{1}, Zhenghong Chen\textsuperscript{2}, Mingzhong Tian\textsuperscript{1}, Fadong Wu\textsuperscript{1}, Robert A.L. Wray\textsuperscript{3}, Yamin Ping\textsuperscript{1}

On the growth of national geoparks in China: Distribution, interpretation, and regional comparison

1 School of Earth Sciences and Resources, China University of Geosciences, Beijing 100083, China. Email: yangcugb@gmail.com
2 Development Research Center, China Meteorological Administration, Beijing 100081, China
3 UOW College and School of Earth and Environmental Sciences, University of Wollongong, Wollongong 2522, Australia

Since the year 2000 China has created 139 National Geoparks; it started under the guidance of the former UNESCO’s Division of Earth Science, and has therefore become one of the pioneers in this aspect. Many National Geoparks in China have been described over the past decade, but an understanding of the range of various landform features and their connection with geological and climatic constraints has not previously been published. Based on an increasing awareness of National Geoparks, the aim of this contribution is to provide a comprehensive overview of the National Geoparks of China by reviewing the geological heritage and their intrinsic linkages with geological and climatic controls. A regional comparison of the widespread clastic and karst Geopark landforms indicates that the development of these terrains can only be understood within a synthesis of tectonic constraints, climatic changes and lithological properties, whereas the variety of types, forms, scales and development patterns reflect processes in various climatic settings.

Introduction

A Geopark is a well-defined area that contains one or more geoheritage sites selected on the basis of scientific importance, rarity, scenic quality, or relation to geological history, events and processes (Eder and Patzak, 2004; UNESCO, 2008). The general perception over the past century or so has been that most geological features are highly resistant and thus do not require protection, and therefore geological surveys have been most commonly linked to the questions of mineral resource exploration and economic development. But as time has progressed, more attention is now being paid to preservation of sites of natural geoheritage, areas that in many cases demonstrate the real and nonrecurring nature of Earth’s evolution (Leman et al., 2008). Establishment of new geoparks can also favor non-traditional economic development based upon geo-tourism and geo-products (Eder, 1999; UNESCO, 2008).

Since 1992, W. Eder (Director of UNESCO’s Division of Earth Sciences) has argued for the designation of new “Geoparks” which focus on the sustainable utilization and conservation of geoheritage sites (Eder, 1999). As a continuation of earlier initiatives, and with support from UNESCO, the International Union of Geological Sciences (IUGS) began in 1995 to compile a global inventory of key geoscience localities and terrains (UNESCO, 156Ex/11Rev, 1999). In response to the development of the geopark concept the European Geopark Network was formed in 2000 (Zouros, 2002), followed in 2001 by the establishment of UNESCO Global Network of National Geoparks. In 2001 a meeting of interested scientists and policy makers at UNESCO’s Paris headquarters took a substantial step forward in promoting the establishment of national or regional Geoparks in collaboration with UNESCO’s Division of Earth Sciences. A further important milestone in the global geoparks movement came in 2004, when an initial Global Geoparks Network (GNN) was established on the basis of 25 geoparks in Europe and China. The GNN has now expanded to 67 Geoparks representing 25 countries from four different continents.

In parallel to the work of geoscientists in other countries, the geoscience community of China attaches great importance to the conservation of geosites, striving for the goal of scientific protection and sustainable development. The conservation of geological sites emerged in China in the 1980s, and has continued ever since in accordance with national laws and regulations, supported by government agencies, and promoted by nongovernmental organizations (Pan, 1995; Zhao and Zhao, 2003). The result of these efforts over the past two decades has been the designation of 139 conservation localities or districts (including the recently established Hong Kong National Geopark) as National Geoparks. Establishment of an additional 325 sites is currently in progress.

Despite their unique geological and scientific importance, the distribution pattern of many national geoparks within China remains poorly documented in the international literature (Zhao and Zhao, 2003; Leman et al., 2008). Reports of a relatively small number of Chinese National Geoparks with more spectacular features are widely scattered throughout the international earth sciences literature (such as karst landscapes in Guangxi of southeastern China or sandstone landforms in Zhangjiajie (forming some of the spectacular backdrops in the movie Avatar). But except for brief summaries by Zhao and Zhao (2003), Sun (2006), and Zhao and Zhao (2009) no
Geological and climatic framework of National Geoparks in China

Tectonic controls

China has a wide range of geological and tectonic settings, owing in large measure to its location on the southeastern edge of the Eurasia Plate, and adjoining the Pacific Plate and Gangdise - Indian plates (Wu, 2001). Many prior studies (Li et al., 2002; Ministry of Land and Resources of the People’s Republic of China, 2004) have shown that the major fault and fracture systems in the region exert a dominant control on landform development, via differential uplift and widening of fractures and joint sets. The basement structure of most of southern China was established by the Wuling-Xuefeng Orogenic Movement (~1400-850 Ma), and during the Late Triassic Indosinian Movement China underwent a complex process of NW-SE extrusion and east-west shearing, producing associated groups of NW-NNW tension-faults and NS and NNNW strike-slip faults. The early Yanshanian Movement during the late Jurassic period (around 160-140 Ma), caused EW extrusion of China and formation of NNE-NS folds together with two sets of strike-slip faults in NNW and NEE directions. The late Yanshanian Movement of late Cretaceous age (around 130-68 Ma), displaced south China from SE to NW, with reactivation and enlargement of faults, uplift and tilting (Wu, 2001).

Juxtaposition of diverse geological features provides an ideal basis for the occurrence of a variety of landscapes (Fig. 2). In China landforms deemed worthy of national geopark status tend to be concentrated along the discontinuities that mark the boundary zones between the three topographic benches that characterize Chinese physiography (Fig. 2). These boundaries are areas of intense tectonic activity. For example, the huge nappes of the Longmen Mountains (Geopark 54), the waves in a river caused by rapid, or undulating landscape in the Dadu Valley (Geopark 59), and the gushing hot springs and volcanic landscapes in Tengchong (Geopark 125; Fig. 3j) are all found along the westernmost and highest geomorphic step. Extensive differential uplift and subsidence along pediment faults along the second geomorphic step has given rise to the impressive red cliffs and waterfalls in the grand Taihang, Wuling, and Nanling mountains (Figs. 4d, 4e, 4f, 4g, 4h). The third, easternmost and lowest, geomorphic step includes terrains corresponding to the Circum-Pacific volcanic belt and is characterized by steep mountains and towering crags, such as those at Yandang Mountain of Zhejiang(Figs. 5f, 5g), Taimushan (Fig. 5h) and Zhangzhou of Fujian (Geopark 103), and Huguangyan of Guangdong (Geopark 136).

Differential tectonic uplift and subsidence in Mesozoic and Cenozoic times has also given rise to many unique local landforms, such as the remarkable hoodoos in Yunnan, the secluded mountain landscapes in Jiangxi, the majestic and beautiful Huashan landforms in Anhui, and the precipitous Songshan terrain in Henan. Integrating joint systems have provided structural control for fluvial incision and glacial erosion, giving rise to the striking pinnacles and peak clusters, narrow ridges and deep gullies in these areas.

The diversity of landforms also reflects the interplay of tectonic and lithologic constraints. For instance, the stepped landforms at Zhangjiajie (Fig. 4f) that are developed on flat-lying intercalated Devonian sandstone and siltstones have been affected by intermittent

Materials and methods

In order to meet the primary objectives of our present study we collected the relevant published references and reports (e.g., Wu, 2001; Zhao and Wang, 2002; Zhao and Zhao, 2003; Ministry of Land & Resources of the People’s Republic of China, 2004; Sun, 2006; Cui et al., 2007; Wei et al., 2008; Zhao and Zhao, 2009). We also incorporate available annual detailed reports of national geoparks and information provided on their websites (Liu, 1999; Li et al., 2002; Wu, 2005; Peng, 2007). Various maps and figures were generated by superimposing the location of the geoparks on topographic and geologic maps. The complex geology and climatic patterns of the large Chinese landmass are summarized in the subsequent section, and provides the framework for the discussion and interpretation of the geoparks. Geoparks are then discussed on the basis of their relief, morphometric features and landform forming processes. In view of their abundance in China, and also the existing international reputation of some of these areas, selected karstic and elastic landforms are then discussed in more detail so as to verify the relative importance of lithologic and climatic constraints.

Geoheritage resources in China

China possesses numerous outstanding and varied geoheritage resources owing in large part to its unique 3-level stepwise geomorphic framework, with elevation descending from west to east (Fig. 1). Regrettably, until the 1980s there were no serious efforts in China to conserve geoheritage resources from unsustainable resource utilization and other intensive anthropogenic activities (Zhao and Wang, 2002). However in the past decade China has seen a rapid growth in interest and demand for geopark protection, and has embraced the international initiatives to develop the geopark concept. Expanding previously proposed classification systems (Zhao and Zhao, 2009), we propose a synthetic classification of the 139 national geoparks already established, and classify these geoheritage resources into 7 categories and numerous subcategories.

The most important of these geoheritage resources are diverse geomorphic features and landscapes, including karst, clastic, glacial, fluvial, volcanic and structural landforms. For centuries these spectacular landforms have attracted researchers of different backgrounds, as well as a large number of tourists from all over the world. Other important geoheritage resources include fossil beds, geohazard and mining sites, geological type-sections, and geological structural features. In order to systematize the description of these various types of resources and facilitate their preservation, the Ministry of Land and Resources of the People’s Republic of China established in 2008 the classification system outlined in Table 1.
Cenozoic uplift processes (Yang et al., 2011). The uplands are deeply dissected and the entire massif has been uplifted 300-500 m along the marginal faults. This has given rise to extensive flat surfaces often separated by steep cliffs, shaped mainly by scarp retreat caused by fluvial sapping and mass failure. Overall, the larger structural lineaments at Zhangjiajie control the major streams and escarpments, but more importantly, the smaller fractures and joints break the rock mass into smaller-size blocks. Thus, whilst the major drainage patterns follow first-order tectonic controls, the spectacular topographic features at this and other geoparks were shaped by the smaller-scale but more densely distributed joints.

Similarly, temporally-variable eruptions have given rise to volcanic rock sequences with variable lithologic characteristics, as evidenced for instance in Zhangzhou National Geopark, and Arxan National Geopark (Fig. 4a). As part of the Circum-Pacific belt, the peri-Pacific region in the stable platform area of eastern China has
experienced four episodes of volcanic activity since the Cenozoic (and, locally, late Mesozoic), forming the ‘East Asia continental rift belt’ (Liu, 1999). The National Geoparks Wudalianchi in Heilongjiang, Fushan in Anhui, Linhai in Zhejiang, Zhangzhou in Fujian, and Huguangyan in Guangdong each display typical characteristics of variable volcanic sequences controlled by their different tectonic settings within the East Asia continental rift belt.

Mass failure triggered by earthquakes or other abrupt geological events is also important in shaping the landforms of tectonically active zones (Pan, 1995). For example, earthquakes have triggered landslides over large areas, and this has been the case in Cuihuashan, Yigong Geopark in Tibet, and Zigong in Sichuan (Fig. 1 and Table 1). However even in presently tectonically quiescent regions, there may be topographic features of past earthquake activity such as extensive relict collapse deposits.

**Climatic zonation**

Many previous studies (Pan, 1995; Zhao and Zhao, 2003; Wu, 2005) have shown the importance of the large range of climate types in China (Fig. 6) in determining the style of denudation and morphology. Nationally-averaged annual rainfall is 630 mm per year and decreases from the southeast coastal areas towards the northwest inland region. The southeast coastal areas of Guangdong, Guangxi, eastern Fujian, Jiangxi, Zhejiang and Taiwan are characterized by a tropical to subtropical monsoon climate, with relatively high annual precipitation of 1500-2000 mm. Annual rainfall in the Yangtze River basin, the Huahe River basin and Qinling area are approximately 1000 mm, 800 mm and 800 mm, respectively. In the Lower Yellow River basin, Weihe River basin, Haihe River basin and most parts of northeast Daxinganling rainfall is around 500-750 mm, and, in contrast, the annual rainfall in the northwest inland region is only 100~200 mm. Further west, the extremely dry Tarim, Turpan and Qaidam Basins of Xinjiang receive less than 50 mm, with the central parts of these hyper-arid basins receiving less than 20 mm annually. Temperatures show a similar trend, decreasing from an average of >20ºC in the southeast coastal areas towards the much colder northwest China. The coldest areas are located in the Qinghai-Tibetan Plateau in the west and in the extreme northeast China, where annual temperatures are < -4ºC.
Table 1. National geoparks in China classified by major geoheritage feature or value

| Classification | Representative national geoparks (number) | Major features of geoheritage resources |
|----------------|------------------------------------------|----------------------------------------|
| A: Geological sections and geological bodies | Liujiang National Geopark, Qinhuangdao (14) | Complete stratigraphic section of North China; marine erosion landforms; granite landforms |
| | Fuping Natural Bridge National Geopark (17) | Archeozoic standard Longquanguan Formation |
| | Jixian National Geopark (24) | Middle-Upper Proterozoic stratigraphic section |
| | Taishan National Geopark (28) | Stratigraphic sections of Neoarchaeozoic to Paleoproterozoic, Cambrian and Early Ordovician; Early Paleozoic fossils; neotectonic landforms |
| | Wutaishan National Geopark (31) | Wutai Group, Hufu Group, Wutai tectonic movement; periglacial landforms |
| | Shennongjia National Geopark (68) | Folded metamorphic basement; Pleistocene palaeoanthropic relics, mountainous glacial, fluvial and karst landforms |
| | Taishan National Geopark (28) | Late Archean-Early Proterozoic stratigraphic unit |
| | Songshan National Geopark (79) | GSSP stratotype profile of Darrwilian Stage reef limestones |
| B: Structural features at different scales | Longmenshan National Geopark (54) | Long-distance nappe structure/Longmenshan tectonic zone |
| | Mulanshan National Geopark, Wuhan (70) | Plate collisional high-pressure belt; Blueschist of metamorphic belt |
| | Baotianman National Geopark, Neixiang (77) | Tectonism; metamorphism; granite forest landforms; Proterozoic-Paleozoic strata |
| | Dabieshan (Liu’an) National Geopark (83) | Stylolite structure; ultra-high pressure metamorphic zone; granulate-facies rocks; granite peak clusters; caves; canyons; volcanic landforms; silicified wood and neotectonism |
| | Wugongsan National Geopark (107) | Structures of metamorphic core complexes; granite peaks and cliffs |
| C: Palaeontology and palaeoanthropology | Fengkai National Geopark (132) | Relics and fossils of ancient human-beings; karst landforms; fluvial landforms |
| C-1: Palaeoanthropology | Juyin Dinosaur National Geopark (1) | Dinosaur fossils of Late Cretaceous |
| | Liujiaxia Dinosaur National Geopark (39) | Larger dinosaur footprints (with an diameter of > 1m) |
| | Zigong Dinosaur and Palaeoorganism National Geopark (60) | Various dinosaur fossils; complete dinosaur skeletons; dinosaur skins |
| | Yunxian Dinosaur-Egg Fossil Cluster National Geopark (69) | Cretaceous dinosaur-egg fossils; Australopithecus; paleoanthropology |
| | Funiushan National Geopark, Xixia (76) | Centralized dinosaur-egg fossils; Qinling orogenic belt |
| | Lufeng Dinosaur National Geopark (122) | Middle-Jurassic dinosaur fauna; Late Late-Miocene Australopithecus; Palaeomining sites |
| C-2: Palaeoanimals | Chaoyang Bird Fossil National Geopark (8) | Jehol fauna with abundant birds, dinosaurs, primitive mammals, earliest flowers, and diverse insects |
| | Shanwang National Geopark (27) | Abundant and perfectly preserved Miocene biota |
| | Anyuan Biocenological National Geopark (58) | Devonian siliceous sponge reef |
| | Jingning Fossil Cluster National Geopark (117) | Late Triassic marine reptile and crinoids fossils showing eco-environment and palaeotaphonomy |
| | Chenjiang Ancient Fauna National Geopark (121) | Early Cambrian (0.7-0.8 Ga) Explosion with simultaneous emergence of dozens of biological categories |
| C-3: Palaeobotany | Yangning Silicified Wood National Geopark (21) | Clusters of in-situ buried silicified wood |
| | Qitai Silicified Wood-Dinosaur National Geopark (45) | Silicified wood fossils; dinosaur fossils; yardang landform |
| | Sheshong Silicified Wood National Geopark (61) | Silicified wood and palaeoecological fossils |
| | Xinchang Silicified Wood National Geopark (92) | Silicified wood of Cretaceous; Danxia landforms |
| D: Minerals and ore deposits | Koktokay National Geopark, Fuyun (44) | Relics of mining for granite pegmatite-type rare metal deposit; earthquake landforms; granite landscapes |
| E: Geomorphic features and landscapes | Yichun Granite Stone-forest National Geopark (2) | Granite peak clusters, forests and pillars; Indosinian granites with fractures and joints; gravity collapse |
| E-1: Rock landscapes | Hexigen National Geopark (12) | Granites with horizontal joints; man-like and objective-like granite pillars |
| | Yimengshan National Geopark (29) | Granite peak clusters and forests; gems and jades |
Table 1. National geoparks in China classified by major geoheritage feature or value

| Classification | Representative national geoparks (number) | Major features of geoheritage resources |
|----------------|------------------------------------------|----------------------------------------|
| **Granite landscapes; cone-shaped peaks; spherical weathering** | Shenlingzhai National Geopark, Luoning (75) | Granite landscapes; cone-shaped peaks; spherical weathering |
| **Granite peak forests and stone egg landforms; gravity collapse; fluvial erosion** | Chayashan National Geopark (80) | Granite peak forests and stone egg landforms; gravity collapse; fluvial erosion |
| **Granite peak clusters; ultra-high pressure metamorphic belt; Quaternary mammal fossils** | Tianzhushan National Geopark (84) | Granite peak clusters; ultra-high pressure metamorphic belt; Quaternary mammal fossils |
| **Granite peak clusters and forests; waterfalls** | Guniujiang National Geopark, Qimen (86) | Granite peak clusters and forests; waterfalls |
| **Granite forest peak; rock pillars; grotesque peaks; queer rocks; deep and secluded canyons; warm springs; spectacular pines** | Huangshan National Geopark (87) | Granite forest peak; rock pillars; grotesque peaks; queer rocks; deep and secluded canyons; warm springs; spectacular pines |
| **Granite with potassic vugs and fissures; granite hoodoos; peak cluster and cavities; gravity collapse; marine erosion landforms** | Taimushan National Geopark, Fuding (96) | Granite with potassic vugs and fissures; granite hoodoos; peak cluster and cavities; gravity collapse; marine erosion landforms |
| **Granite peak clusters; volcanic landforms** | Shiniushan National Geopark, Dehua (101) | Granite peak clusters; volcanic landforms |

**Clastic landforms**

| Classification | Representative national geoparks (number) | Major features of geoheritage resources |
|----------------|------------------------------------------|----------------------------------------|
| **Sandstone peak clusters; faults and joints; Pleistocene valley glaciers** | Bingyugou National Geopark, Dalian (9) | Sandstone peak clusters; faults and joints; Pleistocene valley glaciers |
| **Red cliffs and long walls; sedimentary profiles and bedding structures; Valleys; peak clusters; stepped landforms; basalt eruption** | Zhangshiyian National Geopark, Zanzhuang (18) | Red cliffs and long walls; sedimentary profiles and bedding structures; Valleys; peak clusters; stepped landforms; basalt eruption |
| **Cliffs; peak forest; peak clusters; valleys** | Wu’an National Geopark (20) | Cliffs; peak forest; peak clusters; valleys |
| **Canyons; valleys; gorges; red cliffs and long walls; residual hills; waterfalls; karst caves** | Huguan Canyon National Geopark (33) | Canyons; valleys; gorges; red cliffs and long walls; residual hills; waterfalls; karst caves |
| **Red cliffs and long walls; valleys; unconformity and ancient strata; ancient and modern water conservancy projects** | Kongtongshan National Geopark, Pingliang (38) | Red cliffs and long walls; valleys; unconformity and ancient strata; ancient and modern water conservancy projects |
| **Stepped valleys; peak clusters; water landforms; shallow sedimentary structures** | Yellow River Stone Forest National Geopark, Jingtai (40) | Stepped valleys; peak clusters; water landforms; shallow sedimentary structures |
| **Danxia landform and Loess Plateau** | Huoshizhai National Geopark, Xiji (42) | Danxia landform and Loess Plateau |
| **Danxia-type landforms; karst cave and collapses; standard Devonian stratigraphic profiles** | Kanbula National Geopark, Jincheng (48) | Danxia-type landforms; karst cave and collapses; standard Devonian stratigraphic profiles |
| **Cliffs; peak forest; peak clusters; valleys** | Jiangyou National Geopark (57) | Cliffs; peak forest; peak clusters; valleys |
| **Canyons; valleys; gorges; red cliffs and long walls; residual hills; waterfalls; karst caves** | Guanshan National Geopark (71) | Canyons; valleys; gorges; red cliffs and long walls; residual hills; waterfalls; karst caves |
| **Red cliffs and long walls; valleys; unconformity and ancient strata; ancient and modern water conservancy projects** | Yuntai National Geopark, Jiaozuo (72) | Red cliffs and long walls; valleys; unconformity and ancient strata; ancient and modern water conservancy projects |
| **Stepped valleys; peak clusters; water landforms; shallow sedimentary structures** | Wangwushan National Geopark (73) | Stepped valleys; peak clusters; water landforms; shallow sedimentary structures |
| **Danxia landform; red cliffs and lone walls; flat caves; natural bridges; dinosaur fossils** | Daimeishan National Geopark, Luoyang (74) | Danxia landform; red cliffs and lone walls; flat caves; natural bridges; dinosaur fossils |
| **Various peak pillars, prisms, precipices, and overhanging rock** | Qiyunshan National Geopark (88) | Various peak pillars, prisms, precipices, and overhanging rock mirrored on lake; queer rocks; caves; valleys |
| **Danxia landform; karst landforms; typical stratigraphic profiles** | Taining National Geopark (98) | Danxia landform; karst landforms; typical stratigraphic profiles |
| **Quartz sandstone landforms with mesa, square mountain, peak clusters and forests; pillars; valleys; karst caves** | Yong’an National Geopark (100) | Quartz sandstone landforms with mesa, square mountain, peak clusters and forests; pillars; valleys; karst caves |
| **Danxia landform; tafelbergs, peak pillars, canyons and precipices** | Longhushan Danxia Geomorphy National Geopark (106) | Danxia landform; tafelbergs, peak pillars, canyons and precipices |
| **Danxia landform; cavities, valleys, natural bridges, cliffs** | Zhangjiajie Sandstone Peak Forest National Geopark (108) | Danxia landform; cavities, valleys, natural bridges, cliffs |
| **Alpine Danxia landform; glacial relics; modern glacial valleys** | Langshan National Geopark (112) | Alpine Danxia landform; glacial relics; modern glacial valleys |
| **Danxia landform; tafelbergs, peak pillars and precipices** | Feitianshan National Geopark, Chenzhou (113) | Danxia landform; tafelbergs, peak pillars and precipices |
| **Danxia landform, where this typical landform is named** | Liming—Laojunshan National Geopark, Yulong (124) | Danxia landform, where this typical landform is named |

**Karst landforms**

| Classification | Representative national geoparks (number) | Major features of geoheritage resources |
|----------------|------------------------------------------|----------------------------------------|
| **Danxia landform with grotesquely shaped rocks and hills** | Zhanjiangjiejie Sandstone Peak Forest National Geopark (112) | Danxia landform with grotesquely shaped rocks and hills |
| **Quartz sandstone landforms with mesa, square mountain, peak clusters and forests; pillars; valleys; karst caves** | Feitianshan National Geopark, Chenzhou (113) | Quartz sandstone landforms with mesa, square mountain, peak clusters and forests; pillars; valleys; karst caves |
| **Danxia landform; tafelbergs, peak pillars, canyons and precipices** | Liming—Laojunshan National Geopark, Yulong (124) | Danxia landform; tafelbergs, peak pillars, canyons and precipices |
| **Danxia landform; cavities, valleys, natural bridges, cliffs** | Ziyuan National Geopark (127) | Danxia landform; cavities, valleys, natural bridges, cliffs |
| **Danxia landform; tafelbergs, peak pillars and precipices** | Danxiaxiashan National Geopark (131) | Danxia landform; tafelbergs, peak pillars and precipices |

**Kast depressions and dolines; caves; underground streams; standard section of north China**

| Classification | Representative national geoparks (number) | Major features of geoheritage resources |
|----------------|------------------------------------------|----------------------------------------|
| **Dolomite peaks, columns, and cliffs; springs; source of Laishui River** | Benxi National Geopark (7) | Dolomite peaks, columns, and cliffs; springs; source of Laishui River |
| **Karst valleys; peak clusters; granite peaks and cliffs; caves** | Baishishan National Geopark, Laiyuan (15) | Karst valleys; peak clusters; granite peaks and cliffs; caves |
| **Karst caves and stepped landforms in canyons** | Yeshanpo National Geopark, Laishui (16) | Karst caves and stepped landforms in canyons |
| **Limestone karst caves with numerous stalactites, stone flowers, prisms, stalagnites, underground streams** | Lincheng National Geopark (19) | Limestone karst caves with numerous stalactites, stone flowers, prisms, stalagnites, underground streams |
| **Karst valleys; peak clusters; caves** | Shihuadong National Geopark (22) | Karst valleys; peak clusters; caves |
| **Karst hills with spectacular shapes; queer valleys; singular caves** | Shidu National Geopark (23) | Karst hills with spectacular shapes; queer valleys; singular caves |
| **Karst landscapes; glacial landforms; Danxia landforms; canyons** | Xiong’ershansh-Baodugu National Geopark (30) | Karst landscapes; glacial landforms; Danxia landforms; canyons |
| **Travertines; waterfalls; rimstone dams; colorful pools; travertine beach** | Jiating National Geopark, Huzhu (46) | Travertines; waterfalls; rimstone dams; colorful pools; travertine beach |
| **Karst peak clusters; hoodoos; huge cavities; big deep dolines; valleys and waterfalls** | Huanglong National Geopark (55) | Karst peak clusters; hoodoos; huge cavities; big deep dolines; valleys and waterfalls |
Table 1. National geoparks in China classified by major geoheritage feature or value

| Classification          | Representative national geoparks (number) | Major features of geoheritage resources                                                                 |
|-------------------------|------------------------------------------|--------------------------------------------------------------------------------------------------------|
|                         |                                           | Middle-lower karst mountains; geological tectonics; stratigraphic sections; terrestrial heat             |
|                         | Huayingshan National Geopark (63)        |                                                                                                        |
|                         | Longgang National Geopark, Yunyang (64)  | Big deep dolines; caves; canyons                                                                       |
|                         | Wulong Karst National Geopark (65)       | Karst landforms; hoodoos; canyons; natural bridges; caves; deep dolines                              |
|                         | Xishan National Geopark at Lake Taihu,   | Karst caves; lake erosion landforms; tectonic landforms                                                |
| Suzhou (90)             |                                           |                                                                                                        |
|                         | Tian’e Caves National Geopark, Ninghua (99) | Karst caves with Cretaceous fish fossils, Pleistocene vertebrate fossils and palaeoanthropologic relics |
|                         | Guzhang Red Carbonate-Rock Stone Forest  | Red carbonate hoodoos; karst landscapes; canyons; caves                                               |
| National Geopark (109)  |                                           |                                                                                                        |
|                         | Jiuhujiang National Geopark (110)        | Karst peak clusters; canyons; caves; natural bridges; waterfalls; lakes; fossils sites                 |
|                         | Fenghuang National Geopark (111)         | Karst canyons; peak forests; tablelands; karst caves; waterfalls                                      |
|                         | Shuanghedong National Geopark, Suiyang (114) | Gypsum crystal flowers in dolomites; warm springs                                                       |
|                         | Zhijindong National Geopark (115)        | Karst clusters and forests; buttes; canyons; karst lakes; cave deposits                               |
|                         | Pingtang National Geopark (116)          | Plateau karst landforms; canyons; deep caves                                                          |
|                         | Wumengshan National Geopark, Liupanshui (118) | Karst caves and canyons; plateau karst landforms; fossils sites and palaeoanthropogenic relics         |
|                         | Xingyi National Geopark (119)            | Karst peak clusters and forests; valleys; waterfalls; Keichousaurus hui fossils                       |
|                         | Shilin Karst Peak Forest National Geopark (120) | Karst hoodoos; sword-shaped pinnacles; peak clusters; caves; waterfalls                              |
|                         | Dushiwai Karst National Geopark in Leye, | Funnels, valleys, peak clusters, and natural bridges formed by underground streams; cave deposits       |
| Baixe (126)             |                                           |                                                                                                        |
|                         | Xiangqiao Karst National Geopark, Luzhai (128) | Karst landforms; chick-like peak clusters and forests; natural bridge; waterfalls                      |
|                         | Fengshan Karst National Geopark (129)    | Karst landforms with high peak forests and deep depressions                                             |
|                         | Lingxiaoan National Geopark, Yangchun (135) | Karst landforms and caves; underground river; palaeoanthropologic relics; peak flying from afar       |
| Loess landforms         | Luochuan Loess National Geopark (36)      | Loess landforms; standard loess section; loess landforms                                                |
| Aeolian landforms       | Alxa Desert National Geopark (13)         | Deserts and embedded lakes; aeolian landforms                                                          |
|                         | Yardang National Geopark (41)             | Grotesquely shaped landforms                                                                          |
|                         | Zanda Clay Forest National Geopark (50)   | Soil forest landforms                                                                                  |
| E-2: Volcanic landforms | Wudalianchi Volcanic National Geopark (3)  | Volcanic landforms; volcanic lakes; volcanic lavas                                                   |
|                         | Jingpohu National Geopark (5)             | Volcanic landforms; lava tunnels; volcanic craters; water landforms; granite landforms                |
|                         | Jingyu Volcano and Warm Mineral Spring    | Longgang volcanoes; lava plateau; volcanic cones; Maar Lake; mineral springs                          |
| Cluster National Geopark (6) |                                           | Volcanic landforms; warm springs; granite peak forests; rock mortars                                  |
|                         | Arxan National Geopark (11)               | Volcanic landforms; ultra-high pressure metamorphism; magmatic intrusion                            |
|                         | Jinggangtai National Geopark, Xinyang (81)| Volcanic rocks; volcanic cones; craters; cinders; lava flows                                          |
|                         | Fushan National Geopark (85)              | Shield volcanic clusters; volcanic columnar joints and hoodoos; river stone layers                     |
|                         | Luhe National Geopark (89)                | Late Cretaceous volcanic rocks and landforms; columnar joints; pterosaurs and bird fossils             |
|                         | Linhai National Geopark (93)              | Early Cretaceous huge calderas; volcanic eruption remains; caldera collapse; resurgence and rejuvenation; volcanic peaks and canyons; waterfalls |
|                         | Yandangshan National Geopark (94)         | Coastal volcanic lavas; basalt columnar joints; volcanic fumaroles and cones                          |
|                         | Zhangzhou Littoral Volcanic Geomorphy     | Modern volcanic landforms; various warm and hot springs; sinter                                        |
| National Geopark (103)  |                                           | Volcanic craters; volcanic-sedimentary sections; coral reef                                          |
|                         | Tengchong Volcano and Geothermal National | Volcanic landforms; Maar Lake; lava structures                                                       |
| Geopark (125)           |                                           | Basic volcanic rocks; Holocene dormant volcanoes; more than 40 volcanic cones; lava tunnel; mineral springs |
|                         | Weizhoudao Volcano National Geopark,     | Volcanic landforms; Maar Lake; lava structures                                                       |
| Beihai (130)            |                                           | Basic volcanic rocks; Holocene dormant volcanoes; more than 40 volcanic cones; lava tunnel; mineral springs |
|                         | Xiqiaoshan National Geopark, Foshan (133)| Volcanic cones; trachytic rocks; canyons and waterfalls; mining sites and palaeoanthropogenic relics |
|                         | Huguangyan National Geopark, Zhanjiang (136)| Volcanic landforms; Maar Lake; lava structures                                                       |
|                         | Shishan Volcano Cluster National Geopark, | Basic volcanic rocks; Holocene dormant volcanoes; more than 40 volcanic cones; lava tunnel; mineral springs |
| Haikou (138)            |                                           | Volcanic landforms; marine erosion landforms                                                           |
|                         | Hongkong National Geopark (139)           |                                                                                                        |
| Classification | Representative national geoparks (number) | Major features of geoheritage resources |
|----------------|------------------------------------------|----------------------------------------|
| **E-3: Glacial landforms** | | |
| Ningwu Ice Cave National Geopark (32) | Glacial relics and ice caves; periglacial landforms; granite spherical weathering landforms |
| Kanas Lake National Geopark, Burqin (43) | Quaternary glacial relics; glacial barrier lakes; cirques, terminal moraines, U-shaped valley, boulders, horns, striae; geological tectonic relics |
| Kunlunshan National Geopark, Golmud (47) | Mud-volcanic ice hummocks; palaeoglacial remnants; tectonic earthquake relics |
| Nyansboyeshizer National Geopark, Jigzhi (49) | Modern glaciers; glacial landforms; plateau peak forest landforms |
| Haibulugou National Geopark (52) | Modern low-altitude glaciers, horns, cirques; warm springs |
| Siguniangshan National Geopark, Golmud (53) | Quaternary glacial landforms; pyramid peaks, cirques, U-shaped valleys; Birthplace of Quaternary glacial research in China; integrated sections; glacial relics and nominated palces; cirques, horns and U-shaped valleys; glacial striae and boulders; Jiangnan ancient stratigraphic section; fault-block mountains |
| Lushan Quaternary Glaciation National Geopark (105) | Quaternary glacial relics; horns and cirques; precipitous fault depressions; tectonic orogeny |
| Cangshan National Geopark, Dali (123) | |
| **E-4: Fluvial landforms** | | |
| Yellow River Delta National Geopark, Dongying (26) | Water bodies of Yellow River Delta; sedimentary features; ancient coast relics; shell dykes |
| Daduhe Canyon National Geopark (59) | River canyons; gorges; lane valleys; Quaternary glaciers; anthropogenic engineerings |
| Yangtze Three Gorges National Geopark (67) | Canyons; karst and gravity collapses; tufa deposits in karst caves; landslides; stratigraphic-structural profiles; fossil sites; hazard mitigation engineering |
| Yellow River National Geopark, Zhengzhou (78) | Fluvial landforms; loess profiles at the top of Yellow River Delta; geological engineering |
| Chongmingdao National Geopark (91) | Sedimentary features of river delta; muddy tidal flat landforms |
| Baishuiyang National Geopark, Pingnan (97) | Flat rocky riverbed; canyons; fluvial erosion landforms; waterfalls; columnar joints |
| **E-5: Marine erosion landforms** | | |
| Coastal Dalian National Geopark (10) | Marine erosion landforms; sedimentary structures; ductile shear zones; geological and structural profiles; natural boundary between Yellow Sea and Bohai Sea |
| Changshan Isles National Geopark (25) | Marine erosion and deposition landforms characterized by sea stacks, caves, viaducts, cliffs, arches; loess deposition |
| Shenhuwan National Geopark, Jinjiang (102) | Marine erosion landforms; lagoons; ancient oyster reefs; huge ductile shear zones |
| Dapeng Peninsula National Park, Shenzhen (137) | Marine erosion and deposition landforms; palaeo-volcanic relics |
| **E-6: Structural landforms** | | |
| **F: Water landscapes** | | |
| Enping Geotherm National Geopark (134) | Geothermal landscapes; granite geology and landforms |
| **F-1: Springs** | | |
| Enping Geotherm National Geopark (134) | Geothermal landscapes; granite geology and landforms |
| **F-2: Lakes and swamps** | | |
| Xingkaihu National Geopark (4) | Tectonic lake; lake levees; wetland; lacustrine landforms |
| Jiuzhaigou National Geopark (56) | Alpine lakes; springs; waterfalls; torrents; karst landforms; stratigraphic profiles; fossils |
| **F-3: River** | | |
| Yellow River Meander Bends National Geopark, Yanchuan (35) | Meandering river; loess canyon landscapes |
| **F-4: Waterfalls** | | |
| Hukou Falls National Geopark at Yellow River (34) | The biggest waterfall in the main Yangtze River; narrow and deep canyons; headward erosion |
| **G: Environmental geo-heritage** | | |
| Cuhuaisuan National Geopark of the Geologic Hazard of Rock Collapse (37) | Earthquake-induced mountain collapses; barrier lake; granite peak clusters; precipitous cliffs |
| Yi’ong National Geopark (51) | Extensive mass wastings; high mountain and deep canyons; modern glaciers |
| Xiaonanhai National Geopark, Qianjiang (66) | Earthquake relics; collapse and slump blocks; talus; barrier lake; karst landforms; fossils; sedimentary features |
Figure 3. Examples of landform diversity in the transitional zone between the first and second geomorphic levels. Where a and b show Yardang landforms in Dunhuang; c refers to karst landforms of Huzhu in Qinghai; d and e indicate karst landforms in Huanglong; f and g are the glacial landforms of Hailuogou in Sichuan; h and i are plateau Danxia landscapes of Yunnan; and j is the volcanic landform of Tengchong in Yunnan.
Figure 4. Various landforms in the transitional belt between the second and third geomorphic levels. Here, a shows volcanic landform in Arxan; b displays granite peaks of Hexigten; c is karst landform in Shidu of Beijing; d is the dolomite peaks in Baishishan of Laiyuan; e refers to Red Stone Valley in Yuntai Mountain; f is Imperial Brush Peak in Zhangjiajie; g and h are Danxia landforms at Danxia Mountain; i is a karst doline at Pingtang in Guizhou; and j is a doline in Baise of Guangxi.
Figure 5. Different patterns in east coastline areas. Here, a is Xingkai Lake of Heilongjiang; b is Dalian coastline; c indicates Changdao coast of Shandong; d shows granite landforms in Yimengshan; e is Chongming wetland of Shanghai; f and g are granite landforms in Yandang Mountain; h is volcanic rock in Taimushan; i is coastal landforms in Dapeng peninsula in Guangzhou; j is marine erosion landform in Hong Kong.
Although many of China’s national geoparks are located in regions with an annual rainfall of > 400 mm and annual average temperatures of >13°C (Fig. 6), it is clear that climatic variations in China have nevertheless played an important role in shaping its diverse landscapes. Variations in temperature and rainfall determine weathering, transportation and deposition processes, and consequently landscape development. Landforms in the humid tropical zones of southeast China are dominated by chemical and biological weathering, with minimal mechanical weathering and abrasion. In these areas the slopes of clastic and karstic peaks and hoodoos tend to be convex, and are mantled by deeply weathered regolith (Table 1). In the temperate zones of central and north China chemical and biological weathering are not as intense as in the tropics, so that landforms tend to be sharper than those in the tropics, but less angular than those of arid lands. The arid northwestern lands and semi-arid margins are characterized by the development of bold cliffs, sharp slope breaks and a marked topographic expression of structural and lithological discontinuities, because the relatively low rainfall has minimized chemical and biological weathering and, because of a sparse vegetation cover, maximized mechanical weathering.

Active glacial/periglacial and/or frost-related processes and landforms are mainly found in the Qinghai-Tibetan Plateau areas where summits reach elevations of around 2000-3000 m (Figs. 3f, 3g). These landforms are characteristic of glacial carving (such as cirques, horns and U-shaped valleys), and steep slopes with basal accumulations of frost-shattered debris or solifluction deposits. In addition to glacial and periglacial erosion, landforms in these areas are also subjected to processes such as post-glacial stress release, salt weathering and some biochemical weathering. Differences in rock properties such as porosity, fracturing, stiffness and rock strength also affect the development of landforms in these lower temperature regimes.

**Lithologic control**

Rock type is also an important constraint on landform development across China, and has been emphasized by many previous investigators (Pan, 1995; Zhao and Zhao, 2003). The nature of the rock (e.g., igneous, metamorphic, clastic, carbonatic) and the degree of weathering determine the rock’s resistance to erosion and therefore the development of different landscapes. Magmatic and metamorphic rocks are exposed across a large

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![Figure 6. Distribution and variation of climatic zones across China.](image-url)
portion of China, and, because of their relatively greater resistance, often give rise to precipitous mountains and steep cliffs. Widely distributed granites, for example, give rise to steep slopes or abrupt peaks, and are well expressed at Hexigten in Inner Mongolia (Fig. 4b), Yimengshan in Shandong (Fig. 5d), Chayashan and Shenlinzhai in Henan, Tianzhushan, Huangshan and Guniujiang in Anhui, Taimushan and Shiniushan in Fujian, and Sanqingshan in Jiangxi. Quaternary basaltic lava flows are abundant in the northeast, north and southeast coastal areas, and have given rise to lava platforms in northeast China and cinder cones, lava domes, crater lakes, calderas, and other volcanic landforms in Guangxi, Guangdong, Yunnan, and Hainan in southeast China (Fig. 7).

Sedimentary rocks cover approximately 75% of China’s land area and have produced some exceptional landscape features. In the southern part of the Yangtze region, terrestrial red conglomerates and coarse-grained sands deposited in humid-hot environments throughout the Mesozoic and Cenozoic periods, now constitute the base of the cliff-like Danxia terrains of Anhui, Fujian, Jiangxi, Hunan, Guangxi, and Guangdong (Figs. 3h, 3i). When affected by fluvial erosion, relatively soft sands and shales yield flat-topped low hills, mesas and buttes, such as in the red bed terrains of south China (Figs. 4g, 4h).

Clastic landforms

Clastic landscapes are widely scattered across most parts of China (Huang, 1999; Peng, 2007; Qi et al., 2005; Fig. 8). Based on tectonic
uplift rate, annual mean precipitation, vegetation cover, and areal distribution, Qi et al. (2005) and Cui et al., (2007) recognized 3 distinct areas of clastic landforms - Southeast, Southwest, and Northwest areas (Figs. 8, 9). In the Southwestern area high precipitation and active tectonic uplift tends to have favored formation of large scale canyons, steep escarpments (Fig. 9f), and large waterfalls, whereas the plentiful rainfall but minor recent uplift characteristics of the Southeastern area have promoted the formation of peak-group, and isolated peak landforms (Figs.9g, 9h, 9i, 9j). Less mature landforms are found in the cold-dry northwestern areas (Figs. 9d, 9e) and locally in northeast and north China (Figs. 9a, 9b, 9c).

Karst landforms

Because of its wide range of climatic zones China contains a remarkable diversity of karst landscapes that constitute a unique natural heritage (e.g., Luo et al., 2006; Wei et al., 2008). In contrast to other landscapes, variability among karst landscapes is a stronger function of climatic variation, and to a lesser extent lithologic characteristic, than of tectonic activity. Karst topography in eastern China varies with latitude from tropical to subtropical to temperate (Shao et al., 2007; Wei et al., 2008; Figs. 10, 11, and 12), whereas the karst landscapes in western China and on the high Qinghai-Tibetan Plateau are characteristic of arid environments.

Tropical karst peaks are chiefly located in Guangxi, western Guangdong, eastern Yunman and South Guizhou (Figs. 10 and 12), with Koho, hoodoos, tower karst, peak clusters and huge caves being dominant in these regions (Figs. 11i, 11j). The limestone peaks typically have very steep slopes and an average peak cluster density of 2.5 per square kilometer, indicating the primary controls of many surface depressions (dolines) and many large caves and underground river systems.

Subtropical karst landscapes, located in the south flank of the Qinling Range and the Huahei River, are characterized by gentle hills and depressions (Figs. 11g, 11h, 11j, 11k, and 12). Underground rivers in these areas are shorter than those in tropics, and there are less depressions and more dry valleys than the tropical karst areas. Positive topography is subdued, with low gentle hills with an average slope of around 25 degrees. Solution features are less well developed that in the tropical areas, and consist mostly of fissure- and arch-shaped caves.

Dry valleys and remnants of ancient flat hills are subtle characteristics of the temperate-zone karst landscapes, which are otherwise similar to non-karst landscapes (Figs. 11a, 11b, 11c, 11d, and 12). Caves are typically small fissure caves, however springs with large catchment areas and significant flow can be common, as evidenced by Baotu Spring and Nianziguan Spring. Strong downcutting of rivers in some areas, such as the Juma River in Beijing, have produced peak forest landscapes (Fig. 11c).

Karstification in arid or semi-arid zones is more poorly developed, and is chiefly restricted to weathering of limestone along a few cracks (Fig. 11e). Because there are few well-developed cave systems, there is no foundation instability and surface doline depressions do not occur (Fig. 12). Plateau karst landforms in periglacial areas are largely controlled by intense freeze-thaw weathering, and this may give rise to remarkable and unique karstification processes, such as stone hills (Fig. 11e), stone walls, accumulated travertine landscapes (Fig. 11f), some shallow caves in the periglacial slopes, and occasional karst depressions.

Distribution of national geoparks in China in relation to regional geology

As previously described, many of China’s national geoparks are located in the transitional areas between different geomorphic levels (Figs. 1 and 2); for instance, the southeast edge of the Tibetan Plateau is the location of the Yardang landforms of Dunhuang in Gansu and Kanbula in Qinghai, of the plateau karst landforms of Huzhu in Qinghai (Fig.3c) and Huanglong in Sichuan (Fig. 3d, 3e), and of the glacial landforms in Qinghai, Sichuan and Yunnan (Fig. 1, 3f, 3g). Volcanic landscapes occur in southern Yunan Province (Fig. 3j), and volcanic and granitic landforms (Fig. 4a, 4b), as well as clastic and karst landscapes, are often concentrated in the transitional region between the second and third geomorphic levels (cf. Fig. 3h, 3i, 4c-4j). Fluvial landscapes, wetland, and coastal erosional landscapes develop in the adjoining areas, and extend from the third step level to the eastern coastlines (Fig. 5a-5j).

The three latitudinal tectonic belts also control the distribution of geoheritage resources, with the central and southern belts being
Figure 9. Major clastic landforms in China with reference to the national geoparks featured by clastic landforms as indicated in Figure 8. Here, a is sandstone landform in Bingyugou of Dalian, Liaoning; b is quartz sandstone landscape of Yuantaishan, Henan; c indicates clastic landforms in Zhangshiya of Hebei; d, e, and f are the typical Danxia landforms in Huoshizhai of Ningxia, Kanbula of Qinghai, and Laojunshan of Yunan, respectively; g indicates the quartz sandstone landform in Zhangjiajie of Hunan; h, i, and j are the Danxia landforms occurred in Longhushan of Jiangxi, Feitianshan of Hunan, and Danxiashan of Guangdong, respectively.
Yunan, Sichuan, and Guizhou, and locally in Xijiang, Beijing, Henan, Hubei, Zhejiang and also Northeast China. Coastal erosion and island landscapes concentrate along the eastern coastline.

Figure 10. (a) Distribution of the major karst landform areas in China (modified from Wei et al., 2008) and showing the transect illustrated in Figure 12; (b) Localities of national geoparks with karst landforms in China.

Geographical distribution of national geoparks in China

Geoheritage resources in China can be divided into 7 regions on the basis of geological-geomorphic features as well as local characteristics of socio-economic development (Fig. 1 and Table 2).

Zone I covers most of Northeast China and eastern Inner Mongolia and is characterized by volcanic landforms, as well as Quaternary glacial and periglacial features. Volcanic cones, craters, volcanic lakes, and coarse pyroclastic ejecta are widely distributed in eastern Inner Mongolia, Heilongjiang, and Jilin Changbai Mountains (Fig. 4a). Remains of quaternary glaciers, ice sheets, permafrost, and lakes (Fig. 5a) are scattered throughout the Songnen Plain, southwest Heilongjiang.

Because of the relatively stable North China platform, Zone II, which includes much of North China and southern Northeast China, preserves fairly complete stratigraphic sections and valuable paleontological remains. These include the Middle-Late Proterozoic type section in Tianjin, the Cambrian section in Shandong, Mesozoic Jehol biotas in western Liaoning and eastern Inner Mongolia, dinosaur-egg fossils in Henan, and the famous Peking Man Site at Zhoukoudian near Beijing. Coastal landforms in these areas preserve features of marine erosion and island landforms, such as in Golden Pebble Beach in Dalian and Changdao (Fig. 5b, 5c).

Zone III corresponds to Central China and the coastal areas of South China. This zone includes the provinces of Hunan, Hubei, Jiangxi, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Hainan and southern Anhui. The chief geological heritage resources in this zone are the Danxia red sandstone landforms, coastal landforms and volcanic landscapes (Figs. 4f-4j, 5e-5j). The spectacular Danxia landforms, incised in Mesozoic red sandstone, are largely the result of erosion in a humid climate with abundant rainfall. Coastal landforms exemplify marine geological processes. Volcanic landforms occur in Yandang Mountain (Zhejiang) and Huguangyan (Guangdong).

Zone IV encompasses the provinces of Guizhou, Chongqing, Guangxi, Yunnan and most of Sichuan in Southwest China in which the most important geoheritage resources are fossil localities and karst terrains. Palaeontological remains in this area are varied, including the Cambrian Kaixi fauna of Jianhe in Guizhou, the Cambrian Chengjiang fauna of Yunnan, Mesozoic vertebrates, chiefly marine reptiles and dinosaurs in Xingyi and Guanling (Guizhou), Zigong (Sichuan), and Lufeng (Yunan). The hot and humid climate has combined with carbonate sequences to give rise to widespread karst landscapes, including karst peaks, towers, caves, canyons, dolines, and travertine springs, terraces and waterfalls (Fig.3d, 3e).

The Shaanxi-Gansu Loess Plateau defines Zone V, and includes most of Shaanxi and Gansu provinces. This area is characterized by arid climates and from a geoheritage perspective is the worldwide type-locality for loess landforms and related fluvial landscapes. River erosion is responsible for the generation of various loess landforms, such as loess mesas, ridges, hills, ditches and columns in Luochuan of Shaanxi. The Yellow River has actively changed course in historical times, and has given rise to river terraces, large meandering river systems and other fluvial landforms, chiefly in Yanchuan (Shaanxi).
Figure 11. Major karst landforms in China with reference to the national geoparks characterized by karst landscapes indicated in Figure 10. Note that, a is karst landform in Benxi Water Cave of Liaoning; b, c, and d are the karst landscapes in Shihuadong of Beijing, Yesanpo of Hebei, and Xiong’ershan of Shandong, respectively; e and f are the typical karst landforms in Huzhu of Qinghai and Huanglong of Sichuan; g is karst topography in Tai Lake of Jiangsu; h and i are the representative karst landscapes in Wulong of Chongqing and Shilin of Yunnan; j shows the karst landform in Guzhang of Hunan; k represents the Tian’e Cave in Ninghua of Fujian; l displays the karst cave in Yangchun of Guangdong.
Zone VI covers the Northwest China, including Xinjiang, western Inner Mongolia, Ningxia and western Gansu. The most important geological heritage resources are aeolian landforms, including Yardang landforms in Dunhuang (Fig.3a, 3b), Gansu Province, high mountain valleys and the glacial landforms in Tianshan. Fossils are also abundant, and include silicified wood in Qitai and dinosaur fossils in Gansu.

The Plateau Area of Tibet, Qinghai and western Sichuan correspond to Zone VII, and the geoheritage includes glacial landforms, mountains and canyons, and salt lakes. The area includes many active glaciers in Tanggula, the Himalayas and other mountain ranges. It also includes the Brahmaputra Grand Canyon and Qinghai Lake. Intensive Cenozoic Himalayan tectonics is responsible for the formation of the Shigatse ophiolite belt in Tibet.

Concluding remarks

The recent designation of many new geoparks in China has renewed local and more recently international interest in China’s varied range of landforms. The nation-wide overview of national geoparks presented here shows that the diversity of geoheritage resources is a good representation of the natural environments and landscape forming processes (functions of tectonics, climate and rock characteristics) found throughout China. Many national geoparks are

| No. | Zoning | Major regions | Primary geoheritage resources (serial number of typical National Geopark(s)) |
|-----|--------|---------------|--------------------------------------------------------------------------------|
| I   | Most parts of Northeast China and eastern Inner Mongolia | Heilongjiang, Jilin, north Liaoning and Eastern Inner Mongolia | 1) Volcanic landforms (11)  
2) Glacial and frozen remains (9) |
| II  | North China and southern Northeast China | Southeast and west Liaoning, Beijing, Tianjin, Hebei, Shanxi, Shandong, most parts of Henan, southeast Inner Mongolia and northern Anhui. | 1) Stratigraphic section (24)  
2) Paleontology (8, 30, 76)  
3) Marine geoheritage (10, 95) |
| III | Central China and coastal areas of Southern China | Hunan, Hubei, Jiangxi, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Hainan and southern Anhui | 1) Danxia landform (88, 98, 100, 106, 112, 113, 127, 131)  
2) Coastal landform (137)  
3) Volcanic landform (93, 94, 103, 133, 136, 138) |
| IV  | Southwest China | Guizhou, Guangxi, Yunnan and most Sichuan | 1) Palaeontology and palaeoanthropology (58, 60, 61, 117, 119, 121, 122)  
2) Karst landscapes (55, 62, 63, 114, 115, 118, 119, 120, 126, 128, 129) |
| V   | Shaanxi-Gansu Loess Plateau | Most of Shaanxi, Gansu, eastern and western Shanxi | 1) Loess landform, including plateau, beam, hilly, ditch, loess column (36)  
2) Fluvial and waterfall landforms (34, 35)  
3) Canyon (33, 40) |
| VI  | Northwest China | Xinjiang, western Inner Mongolia, Ningxia and Western Gansu | 1) Aeolian landforms (13, 41)  
2) Canyon  
3) Glacial landforms (12, 43)  
4) Palaeontology and palaeoanthropology (39, 45) |
| VII | Tibetan Plateau | Tibet, Qinghai and western Sichuan | 1) Glacial landform (47, 49, 52, 53)  
2) Canyon (59) |
located within the transitional areas between the countries west to eastward declining geomorphic level, and their distribution is also controlled by latitudinal tectonic belts. Regional climatic variations are significant throughout China, and these clearly are also a critical factor in the variability of landform development. Lithological variability is also seen to be important. Because of their wide distribution, elastic and karst landforms are of particular interest to Chinese geomorphologists, and have thus far been the most internationally publicized of the Chinese geoheritage. However it is very clear that a vast range of important geoheritage sites are very common within China, and much is now being done within China to recognize, protect and manage these locations as National and Global Geoparks.

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Guifang Yang is Associate Professor in Geomorphology and Quaternary Geology at China University of Geosciences, Beijing (CUGB). She got her PhD in Quaternary Geology with a thesis on Paleoclimatic reconstruction at China University of Geosciences, Wuhan in 2003. Since 2005, she serves as professional staff at China University of Geosciences, Beijing and coordinator of Chinese projects of Geomorphology and Quaternary Paleoenvironment. Her other principal professional interest is improving public awareness of earth science by making relevant geoscience information available to students and the general public.

Zhenghong Chen obtained his PhD in Philosophy of Science and Technology from Beijing Normal University in 2009. Currently he is working as an Assistant Professor at Development Research Center, China Meteorological Administration (CMA). He specializes in meteorological hazards research and works for Development Research Center at CMA. His current research includes policy assessment of meteorological science and technology and enhancement of meteorological emergency management.

Mingzhong Tian is full Professor in Geomorphology and Quaternary Geology from China University of Geosciences, Beijing (CUGB). He is a leader of several Chinese projects related to geomorphology and Geopark construction. He has published over 80 papers and more than 10 books ranging from Quaternary geology, geomorphology, geopark planning and management.

Fadong Wu is a full Professor in Sedimentology and Quaternary Geology from China University of Geosciences, Beijing (CUGB). He is a leader of Chinese projects concerned with Geopark construction and management, Technique Consultant of various national geoparks in China. His research interests span a range of topics within applied geomorphology, Quaternary paleoclimatology, and sedimentology. He has authored/coauthored over 60 publications and several books covering sedimentology, geopark planning and management.