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Hua Peng
School of Geography and Planning
(1956–2018) Sun Yat-sen University
Guangzhou, China

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Foreword By Zhijiu Cui

The author of this book was the academic leader of China Danxia landform research, the team leader in China Danxia Application for World Natural Heritage and the chairman of Red Beds and Danxia Geomorphology Working Group of International Association of Geomorphologists (IAG). Since the writing purpose of this book is international, this book is the most professional and authoritative work with higher scientific value in this field.

Danxia landform is a type of distinctive landform which was first named and developed in China. It is considered as a major contribution from Chinese scholars to the world earth science by international experts. A Danxia landform working group was established by IAG in order to call for international recognition and global research. Nowadays, China Danxia has been included in the World Natural Heritage. The six heritage sites introduced in this book are the most in-depth research cases. This book systematically introduces the results of Danxia landform and the typical cases of six heritage sites. If the English version could be published, it will exert significant guiding influence on future international Danxia landform research, which is conducive to the international promotion of China Danxia landform. In fact, the results of Danxia have resonated with international scholars in many ways.

This book is a high-level scientific work, which is of high readability for its rich illustration and fluent words. Also, this is a good book for its high-level science popularization. There are few articles on China sandstone landform research that are published internationally, and Danxia landform is a kind of sandstone landform. As a result, we can say that this book has filled this gap since the research on China Danxia landform has received great attentions by international scholars.

The author of this book dedicated his life to Danxia landform research. He has explored Danxia landform in most of China, and he has much communication and resonance with me. His expiration makes me sad and heart-broken. Writing this prologue could be a spiritual communication between us. May we memorize and learn from him.

November 2018

Zhijiu Cui

Foreword by Piotr Migoń In memory of Prof. Hua Peng

It is my great privilege to write the foreword to the “China Danxia” book—an important contribution to geomorphology and the testament of lifelong dedication of Prof. Hua Peng to the Danxia landscapes of China. I feel both honoured and very sad, wishing that we could discuss plans of further collaboration, rather than I reflect upon the loss of a distinguished scientist who left us so early.

I recall meeting Prof. Hua Peng for the first time in the year 2000, during my first visit to China, when I was privileged to attend the Thematic Conference of the International Association of Geomorphologists in Nanjing. Knowing very little about China at that time, I looked with awe at photographs contained in his presentation, showing unbelievably beautiful landforms from the Guangdong Province. Then I learnt that they are predominantly from sandstone and denoted as Danxia in China. I was lucky to receive a publication from him, with his signature, which I consult until today as researching sandstone tablelands and cuestas is among my own main research topics.

Then we met again in autumn 2007 when I was involved in an international team of experts helping the Chinese colleagues to develop the World Heritage application for China Danxia. Our contacts intensified and two years later a kind invitation came to me to attend the 1st International Conference on Danxia Landform, in Hua Peng’s own playground—the beautiful Danxiashan. This conference and associated field trip exposed me to more of Danxia and both of us shared the view that such awesome sceneries do not only belong to China, but the entire world, and from scientific point of view are significant globally.

Thus, the next step was to submit a joint proposal to the International Association of Geomorphologists to create a Working Group dedicated to Danxia geomorphology. It came into effect in summer 2009 and has continued over the following years. The impressive list of activities of the Group is the best evidence of personal dedication, energy and vision that typified Prof. Hua Peng. I was impressed how successful he was in coordinating research and organizational efforts of Chinese colleagues, in gathering keen students around him, in establishing international co-operations across the world, and in constantly enlarging the scope of interest, from humid sub-topics of south-east China to the arid north-west, and from monolithic towers of Langshan and Taining to fragile red beds.

In 2012, I was happy to host Prof. Hua Peng in Poland. We discussed further plans for comparative research between Danxia and sandstone formations across the world. Then we met again in Paris, attending the Eighth International Conference on Geomorphology. Unfortunately, I was unable to take part in his major Northwest China research expedition in 2016 for which he kindly invited me. We thought that the plans are simply postponed, but now we know they will never come true with Hua Peng involved. However, I believe the research on Danxia geomorphology, carried out by his students and successors, will continue in his memory. He surely would wish so!

However, although Prof. Hua Peng himself is no longer with us, his spirit is still here and his contribution to Danxia research will not be forgotten. I feel very privileged to have had the personal relationship with Hua Peng and his collaborators and I owe him very much, as it was him who showed me so many hidden gems of Chinese nature. I believe that this book, strong through both the scientific content and impressive images, will contribute to fulfill his dream—that more and more people will know about Danxia, will appreciate Danxia, and will undertake an effort to understand Danxia better.

December 2018

Prof. Piotr Migoń
Institute of Geography and Regional Development
University of Wrocław, Poland
Co-opted Executive member of IAG

Foreword by Fusheng Guo

In the Late Mesozoic in Southeastern China, many continental fault basins were formed with the extension of crustal tectonics. Under the generally dry and hot paleoclimate condition, a set of red beds characterized by red sandstone and conglomerate was deposited, with its thickness reaching several thousand meters.

Since Cenozoic, under the force of tectonic uplift, fault cutting, gravity collapse, weathering and erosion, these red beds have evolved into a series of special landscapes such as red cliffs and distinctive peaks and rocks. In the 1920s and 1930s, when Prof. Jinglan Feng and Prof. Guoda Chen, two famous geologists in China, conducted geological surveys in Jiangxi and Guangdong Provinces, they were attracted by these red cliff landscapes, and that was the opening of Danxia landscapes research.

Over the past 90 years, more than 1000 Danxia landforms have been found nationwide. In recent years, comparable landforms have been found in North America, Europe and Australia. In 2004, 2005 and 2007 respectively, UNESCO approved the establishment of three World Geological Parks, namely Danxiashan in Guangdong, Taining in Fujian and Longhushan in Jiangxi. In August 2010, the “China Danxia”, composed of Chishui in Guizhou, Taining in Fujian, Langshan in Hunan, Danxiashan in Guangdong, Longhushan in Jiangxi and Jianglangshan in Zhejiang, was officially admitted in the World Heritage List. With the joint efforts of Chinese Danxia geomorphologists and local governments, the Danxia geomorphology named in China has finally been introduced to the world as a special geomorphological type, which has been recognized by the international geomorphological circles.

Danxia landform generally has gentle peaks, iconic cliff slopes and gently inclined foothills. As a result, it is briefly defined as “red layer landform with steep cliff slopes”. The word “Danxia” is both visualized and elegant, and the description of “color as *Lilium concolor* Salisb, bright as sunset” gives people infinite beautiful imaginations. Therefore, since ancient times, Danxia geomorphic areas have attracted Taoist and Buddhist believers to build temples in these places. At the same time, it has been favored by the vast number of poets and writers, leaving a large number of poems behind. The scientific research of red beds and Danxia landforms has important theoretical significance and practical value. The red bed sedimentary rock sequence records the important geological information of the earth's evolution in the Late Mesozoic, and the study of the red beds can provide an important basis for explaining the surface sedimentary environment and Paleoclimate in this period.

At present, many Geoparks in China have become teaching and research bases of universities and scientific research institutes. A large number of undergraduates and graduates have become the promoters of Danxia landform, and some of them will definitely become researchers of Danxia landform in the future. The research on Danxia geomorphology can not only improve the level of scientific understanding of geomorphological evolution, but also enrich the scientific content of geoparks, promoting adolescents' love for nature, enhancing their awareness of protecting the environment.

Professor Hua Peng from Sun Yat-sen University devoted his whole life to the study of Danxia landform. His contribution can be summarized as follows, (1) he has improved the scientific theoretical system of Danxia landform and established a more systematic research method; (2) he has summarized the distribution pattern of red beds and Danxia landform in China; (3) he has developed in-depth research on Danxia landform in humid region in South-eastern China, organizing the World Heritage Application among six provinces in South China; (4) he has initiated the study of red-bed desertification and the prelude of large-scale investigation of Danxia landform in arid areas in Western China; (5) as the academic leader of Danxia landform research, he has launched 12 national academic conferences on Danxia landform; (6) he has established the Red Beds and Danxia Geomorphology Working Group in the International Association of Geomorphologists, promoting the international comparative study of Danxia Landform.

Professor Hua Peng was a close friend of mine. I was very sad to know this sudden expiration, which is undoubtedly a great loss to Danxia geomorphology. As a member of Danxia Landform Working Group, we should turn grief into strength, continue to devote ourselves to Danxia landform research, cultivate more young scholars, and promote Danxia landform discipline, which are the things that Prof. Hua Peng would love to see, I suppose. Professor Hua Peng has made outstanding contributions to the application for World Heritage of Danxia landform in China. He is a practitioner of "Clear waters and green mountains are as good as mountains of gold and silver", whose name is not only well known by his colleagues, but also widely spread among the people. I am very glad to learn that his book *China Danxia* will be published soon. This book is a comprehensive summary of Danxia landform in China, much of the content is the innovative achievements first introduced by the author. This book will lead the direction of Danxia landform research in China in the future. At the same time, it will be helpful for international colleagues to understand the special Danxia landform, promoting international comparative study of Danxia landform. I have read it first and would love to recommend it to my colleagues engaged in geological and geomorphological research.

November 2018

Fusheng Guo
Former Vice President of Red Beds and
Danxia Geomorphology Working Group of IAG
Vice President of East China University of Technology

Preface

Danxia landforms were initially named in China. It has been studied for nearly 90 years. After the establishing stage, formative stage, and developmental stage, Danxia landforms have become a relatively mature discipline in China. In May, 2009, the First International Symposium on Danxia Landform was held at Mt. Danxiashan of Shaoguan City in Guangdong Province, the place after which Danxia Landform has been named. Danxia landform then began to be known by international academic circles. During the 7th International Conference on Geomorphology in Melbourne, July, 2009, the Council of IAG (International Association Geomorphologists) approved the establishment of Danxia Geomorphology Working Group, marking the research of Danxia landforms stepped into international stage.

During the 10th National Conference of Danxia Landforms and Tourism Development in July, 2006, suggested by the Department of Langshan Mountain Scenic Area Administration of Hunan Province, a proposal about organizing typical Danxia Landform areas in China for a joint inscription on the list of World Natural Heritage was formed, which got active response from 13 Danxia landform areas in 10 provinces. In December, 2006, with the support from the former Ministry of Housing and Urban-Rural Development and the lead of the construction department of Hunan Province, the work of applying for the award of World Natural Heritage was started. With strict selection, 9 national parks (National Scenic Area) in 6 provinces of South China were nominated, followed by research and demonstration work. After four-year hard work, during the 34th convention of the World Heritage on August 1st, 2010, 6 famous Danxia Landform areas in South China were inscribed on the list of World Heritage Sites.

During this period, the nominated Danxia landform sites organized over 130 experts from various disciplines to work for the inscription. According to the criterions of World Heritage, they unified plans and goals, and conducted fundamental research and integrated demonstration on geology, geomorphology, biology, natural environment, social economy, history and culture of Danxia area. More than 30 experts from IUCN, IAG, IUGS and UNESCO world heritage center were invited to visit and make field investigation at the nominated places. Over 50 symposiums and meetings were organized, more than 20 of which were international meetings. Thus, the application process for the award of World Heritage witnessed the most in-depth research on Danxia landforms. It was also a process with highest degree of participation of the international experts.

Based on the 80-years research on Danxia Landforms in China, this book integrates the latest achievements during the process for the application process of World Heritage. In view of the introduction of the latest scientific system of Danxia landforms systematically, through the case study of six heritage sites, this book explains Danxia landforms from the aspect of geological setting, morphologic characteristics and evolution, biology and ecology, aesthetics value and earth science value, etc. It also briefly introduces the six heritage sites. We expect to provide a systematic introduction of Danxia landforms and typical base sites for colleagues both at home and abroad, and provide reference for the international comparison research on the Danxia landforms. We also hope to provide some information from all works of life for people who have interest in China Danxia World Natural Heritage Sites.

Guangzhou, China

Hua Peng

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Part I

The Basic Questions on Danxia Landform

1

1.1 Introduction of Danxia

Danxia, a terminology, similar to “Karst,” is a unique type of landform and a name of the natural landscape. Literally in Chinese, Danxia is “reddish rays” or “rosy cloud” during sunrise or sunset. In Chinese geoscience circles, the term Danxia was initially designated by Chinese geologists in 1920s to classify specific stratigraphic sequence of red beds that forms hoodoo peaks at a gorgeous mountain named Mt. Danxiashan in Southern China (Feng and Zhu 1928) (Fig. 1.1). What is more, this name also appropriately expressed the natural beauty of the landscape.

After more than 80 years of study and popularization, and as a result of its special landscape esthetic value, Danxia has become almost a household name in China. It has evolved into an independent type of landform by Chinese geoscientists, and it is defined as a kind of landform developed on red beds and featured by steep slopes. This definition can be further explained as an erosional landscape that is formed from thick red beds that have been regionally uplifted, intensively faulted, and deeply dissected by fluvial erosion, weathering process, and mass movement, producing a variety of cliffs and bounded peaks surrounded by deep canyons.

1.2 Research History of Danxia Landform in China

1.2.1 Initial Stage (1928–1949)

Danxia served as a sort of unique landform that has been paid attention at late 1920s. In 1928, Feng Jinglan¹ and Zhu Huisheng for the first time named red beds and related stratum in North Guangdong as “Danxia Formation” and made a vivid description of its lithology and terrain formed. This sort of stratum and terrain classification drew attention of academics, which lay the cognitive foundation of a unique landform.

In 1939, Chen Guoda used the term of “Danxia Topography” for the first time in geology in Gongshui River Basin, Jiangxi. From then on, academics continued to use concepts of Danxia Formation, Danxia Topography, and Chen Stratum Classification.

In this period, some scholars including Zeng (1943) and Wu Shangshi et al. made study and discourse on stratum, lithology, structure, and landform development of South China red beds, which marks that Danxia landform has been advanced from simple concept to academic research.

The research scope mainly centered in Southeast China during this time, and the noun “Danxia Formation” was established. Scholars of this time demonstrated and defined the stratum

¹All the Chinese names mentioned in the full text are surname first.



Fig. 1.1 Danxia landforms at Mt. Danxiashan, China (photographer: Xie Jinshu)

level of Danxia and started this study as an independent landform.

1.2.2 Formative Development Stage (1950–1990)

With the regional geological and comprehensive survey after the founding of the People's Republic of China, the concept of Danxia landform has been widely applied. Zeng Zhaoxuan, especially, continued to process his study on red bed and landform features of South China and published the book of *Rock Topography* which for the first time regarded red bed landform as independent landform type to draw a conclusion. Huang Jin took Danxia terrain as a type of Guangdong Geomorphologic Map and defined "Danxia Topography" for the first time.

During the "Cultural Revolution," the study on Danxia landform came to a halt. After this period, Zeng Zhaoxuan and Huang Shaomin continued to discuss the cultivation and landform features of Southeast China red bed landform. They especially discussed the distribution, petrology features, landform development process, and landform features in the book of *Physical Geography of China: Geomorphology* in 1980. Huang (1982) summarized the mode and features of nearly horizontal red beds slope development under humid climate conditions, which further the study on development mechanism of Danxia landform.

During this period, other scholars had also conducted some study and investigation. These scholars studied Danxia landforms from Hebei, Gansu, Fujian, Anhui, and Guangdong. Meanwhile, tourism geographers started the study on Danxia tourism resource, which directs further study on landscape construction and utilization of Danxia landform.

The regional geological and comprehensive surveys in this period had collected large amount of firsthand references for Danxia landform studies, which helps make more scientific conclusions for defining the age and horizon of red beds. Zeng Zhaoxuan, et al., systematically concluded the Danxia research accomplishments, Huang Jin conducted further discussion on development mechanism of Danxia landform, and Chen Chuankang made studies on landscape resources and utilization of Danxia landform, all of which help make the terms of Danxia landform more widespread. As an independent landform type, academic studies on Danxia have formed a system and started a new branch field.

1.2.3 The Great Development Stage (1991–2008)

Before 1991, studies on Danxia landform were concentrated on individual and sporadic issues. In 1990, Huang Jin took charge the first National Natural Science Foundation Program on Danxia landform studies and started his comprehensive investigation among China Danxia areas. In

1991, the First Symposium on National Danxia Landform Tourism Development was held in Guangdong Mt. Danxiashan, and the establishment of “Danxia Geomorphology and Tourism Development Study Society of China” marked that study on Danxia landform advanced into great development stage.

In this period, Huang Jin worked on Danxia investigation for 3–6 months per year, and his field survey had covered 1000 sites of Danxia landforms area in 28 provinces. His actions enlarged the scope of research area and relevant studies with all his life.

From 1991 to 2008, the study society has held 11 sessions of symposium and published more than 380 papers, and more than 300 papers published in various academic journals. The study contents involve basic theories (definition, classification, feature, sediment, external force, development mechanism), approaches (dating, stress analysis, remote sensing, mapping), historic culture (the relationship between Danxia landform and religion, cliff carving, sculpting landscape, ancient human, cave tomb, cliff coffin, and ancient mountain village), conservation and utilization (resource assessment, planning, conservation and development), and popular science education. In 2006, Danxia landform was for the first time compiled into an independent chapter of *Modern Geomorphology*—a textbook serving for the tenth Five-Year Plan.

However, due to the lack of external exchange on the past Danxia landform research, the international does not understand the situation of China. Until 2000, at the International Association of Geomorphologists (IAG) Nanjing symposium, the bilingual version book *Danxia Geomorphology of China and its Progress in Research Work* was published and the exchange in the conference held by Peng Hua, made the international counterparts a preliminary understanding. In 2004, Mt. Danxiashan was granted the first batch World Geopark as “Danxia Landform Type.” In 2006 and 2008, Taining in Fujian and Mt. Longhushan in Jiangxi were endowed with this denomination successively. In 2006, ten Danxia landform areas in six provinces of South China started a binding application for

World Natural Heritage as “China Danxia.” During these processes, many international experts on geology and geomorphology have taken part in the investigation, consulting and research and organized more than 20 symposiums or consulting in different scales, which promoted the further study on Danxia and the initial international communication.

In the process, promoted and organized by Chen Chuankang and Huang Jin, the studies on Danxia landform and its tourism development have been widespread among the country, presenting a prosperous state of development. Danxia landform, as a branch of geomorphology, has become a crucial growing point of modern geomorphology, and a fundamental framework has formed as an independent subject. Also, international study and communication on Danxia landform start and directly and indirectly serve for economy construction, which attract much attention from society and academic circles.

1.2.4 Internationalization Stage (Since 2009)

While on the subject of this stage, I would like to tell you a story first. At the International Association of Geomorphologists (IAG) Nanjing symposium, in 2000, I gave a parcel of books entitled *Danxia Geomorphology of China and Its Progress in Research Work* to all of the international colleagues. Before long, Robert Young from the University of Wollongong, Australia, mailed me his first edition of *Sandstone Landforms* and expressed his willingness to pay more attention to Danxia landform with the hope that we would have further cooperation. He had promised to attend the feasibility meeting for “China Danxia” which applies for World Natural Heritage with his wife Ann Young in Chishui City, Guizhou Province, in 2007. Due to visa issues, he and his wife did not attend but his Ph. D. student Robert Wray did. Then, due to his poor health, he also did not attend the First International Symposium on Danxia Landform, but again entrusted Robert Wray to express his

regret and bring the latest edition *Sandstone Landforms*. To my great relief, that edition of the book, written jointly by Robert Young, Ann Young, and Robert Wray, increased introductory content of Danxia landform and referred to the main theory system. For the first time, international foremost experts and a book of authority introduced China's Danxia landform and its research. And in that very year, Danxia landform began to step into the international academic stage after 80 years of research in China.

In May 2009, the first international academic conference on Danxia landform was held in Mt. Danxiashan, Guangdong Province, issued a "declaration of Danxia." The conference affirmed the contribution of Chinese scholars, called the international recognition for Danxia landform and international comparative study, as an independent type, Danxia landform really has caught the attention of the international academic community.

On July 7, 2009, in the Seventh International Conference on Geomorphology Melbourne, Australia, the IAG Council approved the establishment of Danxia Geomorphology Working Group, symbolizing Danxia research has been placed onto the board. The scientific aims of the working group are to discuss and confirm the scientific definition that suited to worldwide Danxia landform; to define the essential development conditions of Danxia landform; to demonstrate its developing process; to build up the scientific classification system; to fully understand the global distribution rule of Danxia landform.

Then, in August 2010, the China Danxia world natural heritage series were nominated and included in the World Heritage List. From Oct 2010, two international conferences were held independently or Jointly. In October 2011, IAG Danxia Geomorphology Working Group first meeting and the second International Academic Symposium of Danxia Landform were held in Mt. Danxiashan. In Apr 2012, the 3rd conference of Sandstone Landscapes was jointly held in Europe; In Aug 2013, The Eighth international conference of Geomorphology, IAG Danxia Geomorphology Working Group focused

discussions on Red beds, Danxia landform and Sandstone.

During 2013–2014, joint scientific research project was established between China and Slovakia "Landslide hazard and risk assessment for China Danxia World Heritage Sites"; four researchers were sent to Saint Louis University for exchange and started comparative study of red beds landform between Southeast China and Western USA; eight experts from Slovakia, Canada, and Australia were invited to China Danxia heritage sites to investigate Danxia landform.

In recent years, research on Danxia landforms in China has begun to focus on the quantitative study of weathering processes on red bed rock surfaces, as rock weathering may be considered to be the starting point of many dynamic systems and is also a dominant force in shaping the appearance of Danxia slopes. By using modern lab test techniques to analyze structures, mineralogical and chemical properties of rock samples, Zhu et al. (2009a, b, 2010), Chen et al. (2010) discussed many of the processes responsible for the weathering of red bed rocks. They found that different types of red bed rocks vary in weathering resistance. Sandstones and conglomerates, which contain few clay minerals and pores, are more resistant to weathering processes than those siltstones and argillaceous red bed rocks. These works were among the first to make quantitative analysis on the differential weathering of various lithotypes in Danxia landform area. In terms of biological weathering, Huang addressed that the action of moss, algae, and lichen can accelerate the exfoliation of red bed rocks on Danxia slopes, but the microscale weathering process of Danxia rock layers caused by the physical and chemical action of plants remains unclear.

Additionally, quantitative calculation on the rate of tectonic uplift and cliff retreat in Danxia landform areas also aroused concern from some researchers.

In the recent years, great changes have taken place in the field and direction of research. The Geographical Society of China (GSC) Red beds and Danxia Research Working Group was

founded, with the approval of the Geographical Society of China in 2011. The Red Beds and Danxia Research Working Group of GSC finished the construction of organizational structures and adopted the work program at the 13th National Danxia Landform conference in 2013. Then, at the Eighth International Conference on Geomorphology in Paris, France, IAG made the necessary adjustment to “Danxia Geomorphology Working Group” according to China’s conditions. The name of the working group was changed to “IAG Red Beds and Danxia Geomorphology Working Group”. This was not just a change of name, but a qualitative promotion and extension of the research field, meaning the research field was extended to red beds and problems in red beds. The qualitative promotion means the change from landscape research and forms research to a comprehensive study of underground surface above ground which blends geology, geomorphology, and ecology. The extension also indicates the extension from landscape research to the comprehensive study of the geological environment, geomorphological hazards, ecological security, and land conservation. Also, it increases the contact with the national economy and the people’s livelihood, and the development space of discipline and promotes international cooperation and exchange.

In addition, the special program of the Key Basic Research of the Ministry of Science and Technology of the People’s Republic of China “National basic data survey of Danxia landform,” operated by Professor Peng Hua, was approved by the Ministry of Science and Technology of the People’s Republic of China in 2013. This project is led by Sun Yat-sen University and is participated jointly by six universities or institutions, including Shanghai Jiao Tong University and Nanjing University, etc. Although, Danxia landform, born in China, has been studied for more than 80 years in China, there is a lack of systematic basic research, and the research results are not intact. This five-year project is expected to be the foundation of the construction of the scientific system of Danxia landform. A display system of the basic data of Danxia landform, an

exchange platform of academic research and applied research, a real-time update, and a powerful capability of concurrency for worldwide users will be formed. For the first time, at national scale, the collection of basic data, the construction of Danxia landform’s basic database, and the scientific construction of a sharing platform mark that the “National basic data survey of Danxia landform” was integrated into state scientific planning. It has had a revolutionary impact on the study of China Danxia.

In general, the research history of Danxia landforms in China mentioned above presents a trajectory from early description and classification of features, to process explanation based on data analysis. During this transformation of research approaches, the investigation scales are becoming increasingly smaller and detailed; the traditional qualitative methods of field observations, measurement, and description of weathering features were shifted toward quantitative assessment.

1.3 Basic Concept

1.3.1 The Early Definition

Since Feng Jinglan puts forward “layer Danxia” in 1928, then in 1938–1939 Chen Guoda developed the concept of “Danxia terrain”. Later on there was a long historical period nobody discussed its definition. The research mainly focused on physical, geological structure, color, shape, etc., but there was no lack of combination of description and concept explanation. Not until 1961 was Huang Jin in the preparation of Guangdong Province topographic maps who proposed the definition “Danxia landform is composed by the level or slight changed thick red sandstone, conglomerate, due to rock massive structure and abundant easy for water percolation vertical joints, and after down by running water erosion and the role of gravitational collapse, then forming the steep peaks or mountain terrain.”

Geography Dictionary proposed that the Danxia landform refers to “landforms of Square

Mountain, odd peak, red cliff, grotto and megalith, and so on formed on the great thick red conglomerate” in 1983. The same year *Geological Dictionary* defines as “the thick, gentle attitude, joint development, iron calcium mixed uneven cement red conglomerate, on the combined effect of the differential weathering, gravitational collapse, erosion, corrosion, etc., resulted in the castle-like, pagoda-like, acicular, columnar, rod-like, square-shaped, or hill-like peaks terrain.”

Zeng Zhaoxuan and Huang Jin in 1990 proposed Danxia was “the general name of each kind of red cliffs and strange peaks developed along the vertical joints in thick red sand, conglomerate” in the volume of *Encyclopedia of China Geography*.

Since 1990s, along with people becoming increasingly concerned about Danxia, the discussions about the concepts of Danxia also gradually increased. The concepts can be divided into two broad categories roughly:

First is the descriptive definition, which more comprehensively expressed Danxia landform’s connotation and denotation, such as its material composition, geological structure, growth conditions, and geomorphological features. More representative is Huang Jin, etc., in 1992 amends the concept of descriptive explanation: “Mainly developed above the Mesozoic to Tertiary level or lightly inclined red thick, rigid, vertical joints developed conglomerate, sandstone and other clastic rocks, in the area of intermittently uplift during neotectonic movement, along the rock joints, bedding down by running water erosion, collapse back off, weathering and wave erosion, karstification and wind erosion and other external force, formed flat peaks (or inclined peaks, roof peaks), body steep, flat piedmont with cliff, square mountain, castle rock, rock towers, rock walls, rock peak, rock column, rock mushrooms, cave, rock pile, rock block and so on the strange, dangerous, elegant and beautiful red cliff landscapes, known as Danxia.”

Second is the abstract definition, which more briefly expressed the essence of the attributes of Danxia landform but no explanation of its concept. For example, Huang Jin in 1992 defined

“the red cliff and red wall and its related landform formed by the red clastic rock formation called Danxia landform”; Huang Keguang and Chen Zhijun in 1992 defined Danxia landform as “each kind of landform with steep slope face formed by the red clastic rock layer”; Peng Hua in 1993 thought it should add “continental facies” restriction to the red clastic rock, proposed “the Danxia landform is a kind of landform grown on the foundation of red continental clastic rock, and characterized as red wall and red cliff”; afterward, Huang (1995, 1996), etc., all added “continental facies” restriction in the revised definition. The above definitions stipulated Danxia landform the “red continental clastic rock” material composition and the “red cliffs slope” of the essential attribute. And the definition is currently accepted and used by the major part scholars.

Not only with the above differences in the interpretation of the definition, differences also exist in the recognition of Danxia landform. There are three different definitions: the first one is a broad definition, including red limestone and red volcanic rock and so on, no matter what kind of rock it is, every landform with red cliff can be classed as Danxia landform. The second one is a narrow definition, and only the landforms developed in Cretaceous red fluvial and lacustrine facies conglomerate can be labeled as Danxia landform. The third definition falls between the first two, and the landform developed in red beds mainly consists of red continental clastic rock (maybe including non-continental layers) is Danxia landform. The material of this landform is limited, but no limitation to the age of the red beds. Today, this definition is accepted widely by most Danxia researchers.

1.3.2 New Definitions and Explanations

(1) Definition

At present, the Danxia landform is concisely defined as “red beds landform characterized as

scarp slope.” Here, it expressed two essential attribute of the concept, first, the Danxia landform belongs to the red beds landform; second, the Danxia landform’s characteristic is scarp slope.

The reason that has substituted the red continental clastic rock in original definition for red beds is because later studies have discovered that in the arid area and the semi-arid region, some siltstone even argillaceous rock may also grow the very good Danxia landform; also, there are some red rock layer with biological or chemical rocks, some with marine-terigenous facies across, transition phase, and littoral–neritic facies interbedded or laminated. However, the main body stratum of the typical developed Danxia remains red continental coarse clastic rocks, especially sandstone and conglomerate.

The reason that replaces red scarp slope or red wall and red cliff with scarp slope is regional red beds have the big difference in color; some red beds color is not always a distinctive red, even with some other colors sandwich; the red beds scarp slope suffered long-term exposure by weathering, running water erosion, biological role, calcium precipitated in water, or organic matter taken from the top of the slope dyeing, and its surface color will be great changes. Therefore, the scarp slope does not necessarily require the scarp slope must be red, but mainly in the red.

(2) Explanation

Increase growth conditions for the explanation of Danxia landform concept and express as “Danxia landform was the uplifted and fracture cutting red beds in the movement of the earth’s crust in recent geological period, mainly suffering water erosion, weathering, erosion, corrosion, gravity, and so on external force effect and shaped into such landform with the characteristics of scarp slope.” This concept contains two basic elements—the material and shape, and two growth conditions—structure and external force.

- **The material basis for Danxia development is red beds.** Red beds for Danxia development mainly red continental clastic rocks, especially coarse clastic rock which are the conglomerate and sandstone as the main. In right conditions, the non-continental red beds (such as the littoral–neritic facies) or siltstone and mudstone (mudstone-arid areas even containing evaporites) may also develop Danxia. Therefore, the concept of sandstone landform concept cannot properly reflect the taxonomic status of Danxia.
- **Danxia is a prominent scarp slope.** Cliff with variety of scales and patterns is the basic element for forming Danxia Mountain block and canyon valley wall and also the most prominent individuality characteristic of Danxia monomer landform and the community landscape. Some experts think that Danxia scarp slope should be limited to be greater than 60° and more than 10 m. But the reality is that some of the early developed Danxia or old age might not reach the slope. Therefore, Danxia scarp slope can be seen as the bare bedrock’s steep slopes.
- **Danxia development was controlled by the geological structure.** Firstly, Danxia developed in the region that the red beds were uplifted to above the local erosion base; secondly, basin geological structure controlled the spatial pattern of block; thirdly, rock attitude and faults, joints, and other structures controlled the shape of Danxia slope; the fourth is the new tectonic movement created the multi-phase and multi-sexual development of topography.
- **External force is the direct Danxia shaper.** Danxia is a landscape formed by water erosion and the gravity collapse as the main force. After red beds were uplifted, it started to accept the role of physical and chemical weathering, erosion, water erosion, slope gravity, etc., and then carved out a thousand pictures landscape. In addition, the wave action of coastal zone, sandstorm function of arid area, biological action and so on are the

Danxia's shape factors and show the different importance in the different area.

In some former definitions, some scholars' viewpoint contains a description of Danxia landscape, such as cone, castle shape, wall shape, and columnar. The monomer landform landscape expression, such as cluster-like, shaped peaks, peaks, the groups landform landscape expression also have red beds deposition time, the landform landscape esthetics expression, and so on. However, these restrictions do not apply to all Danxia or only belong to Danxia low-level features, and the author thinks that there is nonessential to be included in definition, but can be used as a basis for further classification. In addition, esthetics belong to a perceptual evaluation of the subjective consciousness it should not be the limiting factor to define the landform.

1.4 Essential Characteristics of Danxia Landforms

Red scarp slopes are the most significant feature of Danxia landforms. Huang (1982) summarized the basic slope shapes of nearly horizontal Danxia landforms as "flat top, steep cliff body, gentle foothill." These descriptors, respectively, indicate flat top surfaces controlled by nearly horizontal rock layers; scarp slopes controlled by vertical joints; and gentle colluvial foothills controlled by the internal friction angle of the colluvial rocks (Fig. 1.2). For those Danxia landforms developed at basin margin or near fault zone, they had cuesta characteristics, and the inclined top surfaces were essentially consistent with bedding planes (Fig. 1.2). In some places with intensive tectonic activity, the dip angle of rock layers can reach over 60° , and as a result, the bedding planes can form scarp slopes. Liu and Liu (2003) proposed a minimum relative height of 10 m and a minimum gradient of 55° for the identification of Danxia slopes in field investigation. In addition, Gao et al. (2004a, b) applied the King's hillslope development model to explain the shape and evolution

pattern of Danxia slopes. He suggested that the Danxia slope surfaces can be divided into four parts: convex slope, free slope, debris slope, and concave slope. The major evolution patterns of Danxia slopes are parallel retreat and slope replacement.

Nevertheless, there are a variety of slope morphologies observed in the field. Different bedding inclinations may result in various shapes of Danxia top surface, such as "inclined top, round top, and sharp top"; due to water erosion and lithological differences of rock layers in vertical direction, a great amount of caves and grooves with various shapes are formed on the cliff surface (Peng 2004).

Red cliffs are the most significant feature of Danxia landform.

1.4.1 Basic Slope Morphology

- Sub-horizontal strata: flat top, steep cliffs, and gentle foothill slope.
- Gentle dipping strata: gentle inclined top, steep cliffs, and gentle foothill slope.
- Steep dipping strata: if dip angles of layers are more than 60° , the bedding plane can form scarp slope.

1.4.2 The Complexity of the Slope Morphology

The morphology of Danxia slopes can be very complicated.

- Water erosion type, collapsed slope type, multifactor (e.g., rainwater, wind, ripple) influenced type.
- Undulating slope surfaces due to lithology discontinuity along the bedding.
- Vertical grooves developed on Danxia slopes.
- Spheroid weathering on Danxia slope.
- Rock surface is not always red colored.



Fig. 1.2 Danxia landforms developed on nearly horizontal strata (Left); Cuesta Danxia landforms with monoclinic terrain (Right) (photographer: Hou Rongfeng)

1.5 The Taxonomic Position and Classification System

1.5.1 The Discipline Ownership

In the landscape classification system, the Chinese geologists and geomorphologists give Danxia an appropriate position, namely the Danxia belongs to red beds landform in rock geomorphology. In red beds landform, Danxia as a red beds landform with a characteristic of scarp slopes. In other words, red beds landform without scarp slopes may be the red beds hill or red beds mountain region or red beds mountain hills, so it cannot be called Danxia. Therefore, Danxia is a special kind of red beds landform (Fig. 1.3).

However, the international community has not taken it as an independent type to pay attention, Danxia is often included in the sandstone landform, red beds landform even in tectonic landform, sometimes, it is said to be “false-karst” landform. However, these classifications and views seem to be very difficult scientifically expressing its taxonomy status.

Danxia landforms are one of the most spectacular landscapes globally. However, due to the lack of international academic communication, the great amount of work that has already been done by Chinese scholars on

Danxia landforms is poorly known outside China. Actually, according to the gained data so far, Danxia landforms are not unique in China. Literature shows that red beds, the sedimentary strata that are predominantly red in color due to the presence of ferric oxides and are responsible for the formation of Danxia landforms are widely distributed throughout the world. Many stunning landscapes developed on red beds outside China display a similar appearance with Danxia landforms, such as the sparse, towering buttes in Monument Valley, Arches National Park, Southwestern USA, sandstone peaks Purnululu National Park, Western Australia. Although there is lack of research on “Danxia,” there is not rare research on those similar landforms. These Danxia-like landscapes have not been identified as an independent landform in the international geoscience community, and relevant studies were conducted in the scope of sandstone landforms, or named as “red bed landform”, “pseudo Karst,” or “quartzose Karst”; most of red beds are distributed globally in rainless region, and they are usually researched as arid area landform.

For the development of geomorphology sub-discipline, it is still very weak in the research on this kind of landform. The typical Danxia landform in China is mainly developed from terrestrial coarse clastic rocks (conglomerate or sandy

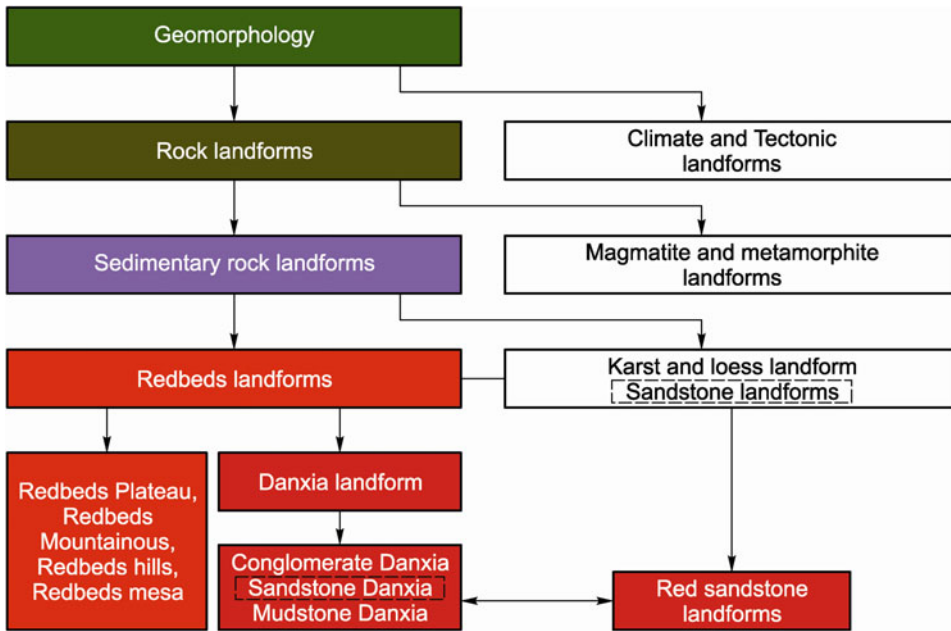


Fig. 1.3 Discipline ownership on Danxia Landform

conglomerate). Thus, it is not suitable to simply classify Danxia to sandstone landform. Landforms vary greatly from red beds; Danxia is just one of them, so that it is also inappropriate to roughly categorize Danxia into red bed landform. Some Danxia landforms involve karst phenomenon; however, it is not a scientific classification to attribute Danxia to “pseudo karst” or “quartzose karst.” Therefore, it is inaccurate to simply classify Danxia into any of the above-mentioned category.

Admittedly, geoscientists have done a lot of research from different perspectives, although terminologies and ways of classification vary. However, we have to acknowledge that despite differences in terminologies, sandstone landforms, red bed landforms, or Danxia landforms are relatively under-researched if compared with other rock geomorphology such as Karst and granite landforms. The research on Danxia landforms is still in its fledgling stage internationally. Therefore, it is necessary for us to join our efforts in the research of it.

1.5.2 The Taxonomic Position and Classification System

As an independent subdiscipline of modern geomorphology, Danxia landform needs a scientific classification system to promote further research. Huang et al. (1992) proposed the first classification system of Danxia landform, on the basis of bedding inclination, climate, development stages, morphology, and existence of overlaid layers and solution weathering. From then on, some other classification systems of Danxia landforms were addressed by scholar (Luo 1994). However, most of them remained focused on the description of individual morphology features; few quantitative indexes have been included in those classification systems.

Based on the previous research, Hua Peng proposed a more integrated classification system of Danxia landforms (Table 1.1). He suggests the first-order classification criteria, including material foundation, geological structure, dominant exogenic forces, landform geometry, and