STEM Education

https://www.aimsciences.org/journal/A0000-0006

STEM Education, 2 (4): 303–317
DOI: 10.3934/steme.2022019
Received: December 2022
Accepted: December 2022

Report

Walking through a 500-million-year geologic history of Yunnan, China: A scientific expedition under the STEM framework

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Academic Editor: William Guo

Abstract: In light of the current situation of STEM education in China, as well as in meeting the need for international education (students studying abroad), Yunnan Key Laboratory of Earth System Science (Yunnan University) and Aufine International carried out a joint scientific expedition on Earth science of Yunnan Province, China. Yunnan is rich in geoscience research and education resources, owing to its unique geographic location to the southeast of the Tibetan Plateau, and its geologic evolutionary history. The expedition was designed under the concept of STEM framework, allowing students to learn the basic geologic knowledge not only in the classrooms, but also in the field, through observing geologic profiles, fossils and rocks, and by using scientific instruments. In addition, students also learned the history of geologic research and experienced multi-ethnic cultures, all of which are elements of STEM education.

Keywords: Earth science, STEM education, Yunnan Province, China

1. Introduction

STEM education was first proposed by the National Science Foundation of the United States. STEM education focuses on solving problems, emphasizes the learning process, pays attention to the deep integration of various disciplines, and strengthens students' innovative thinking, practical ability and core literacy. STEM education has become a new direction of talent training in modern society.

In 2012, the Second National Conference on STEM Education and Application was held in Beijing, China, after which STEM education officially entered the sight of Chinese educational scholars. However, STEM education in China is still in its primary stage, which is not only reflected by the small amount of STEM education research outputs reported by the Chinese educational scholars, but also by the insufficient attention to and recognition of STEM Education in teaching institutions at all levels [1,2]. Therefore, it is necessary to promote healthy development of STEM education in China through various possible ways, which depends on the joint efforts of governments, institutions (universities, middle schools and primary schools), and organizations at all levels.

The first element of STEM education is science. Science and technology are vital for our lives, being the most important driving force for the development of human civilization. However, science education itself has shown a declining trend in recent years. One of the reasons observed is the decreasing interest of students in universities, middle schools and primary schools. To enhance students' interest in science, it certainly involves many aspects of social issues, one of which is popular science education. It is well believed that inspiring students at their young ages through popular science education is an important path.

Earth science, closely related to energy, resources, environment and so on, is a typical practical (applied) scientific discipline, which integrates science, technology, engineering and mathematics. Therefore, Earth science is one of the best disciplines to carry out STEM education.

At the same time, the rapid development of international education (i.e. overseas education for Chinese students) in recent years has arisen a strong demand for STEM education for Chinese students. This also provides impetus for the development of STEM education. As a famous intermediary institution for studying abroad, Aufine International firmly seized this opportunity, cooperated with the Key Laboratory of Earth System Science of Yunnan Province, and proposed to carry out a scientific expedition on Yunnan Earth Science (referred to YNEES hereinafter), which is a beneficial attempt and a successful practice case under the framework of STEM. From the perspective of STEM education, this paper introduces the design concept, organization and implementation of YNESE, and makes a simple effect analysis, with a view to providing cases for STEM education in China.

2. Design concept and framework of YNESE

2.1. Earth and Earth science in the eyes of non-specialists

We live on Earth and have contact with the Earth every day. However, for non-specialists, especially for young people, the Earth appears mostly to be just lands, seas, skies, animals, planets and human beings (Figure 1a). Moreover, we are using or in contact with buildings, cars, mobile phones and electricity, and so on, every day, and curiosity often drives us to wonder: *Where do these things come from*? If we realize that these things are basically taken from the Earth, we will continue to ask: *How did the Earth's resources come into being, and how were they discovered, acquired and used*? *What does it look like under the Earth's surface*? *Does the Earth have a past*? If so, *what would its past look like*? *How did the Earth evolve into what it is today*? *Will the resources on the Earth be exhausted*? *Can the Earth's environment support the future of mankind*? These questions are not only for non-specialists, but also the most basic scientific and engineering problems faced by Earth scientists as well. In order to carry out exchanges between scientists and students in primary and secondary schools in the field of Earth science, Aufine International has established an official WeChat

account: “Kid’s Earth Science” (Figure 1b). The Key Laboratory of Earth System Science of Yunnan Province has set up an official WeChat account “e-Earth” (Figure 1c). The establishment of these official accounts is to popularize Earth science and outreach the scientific frontier to the public and primary and secondary students, which is a typical attempt of STEM education.

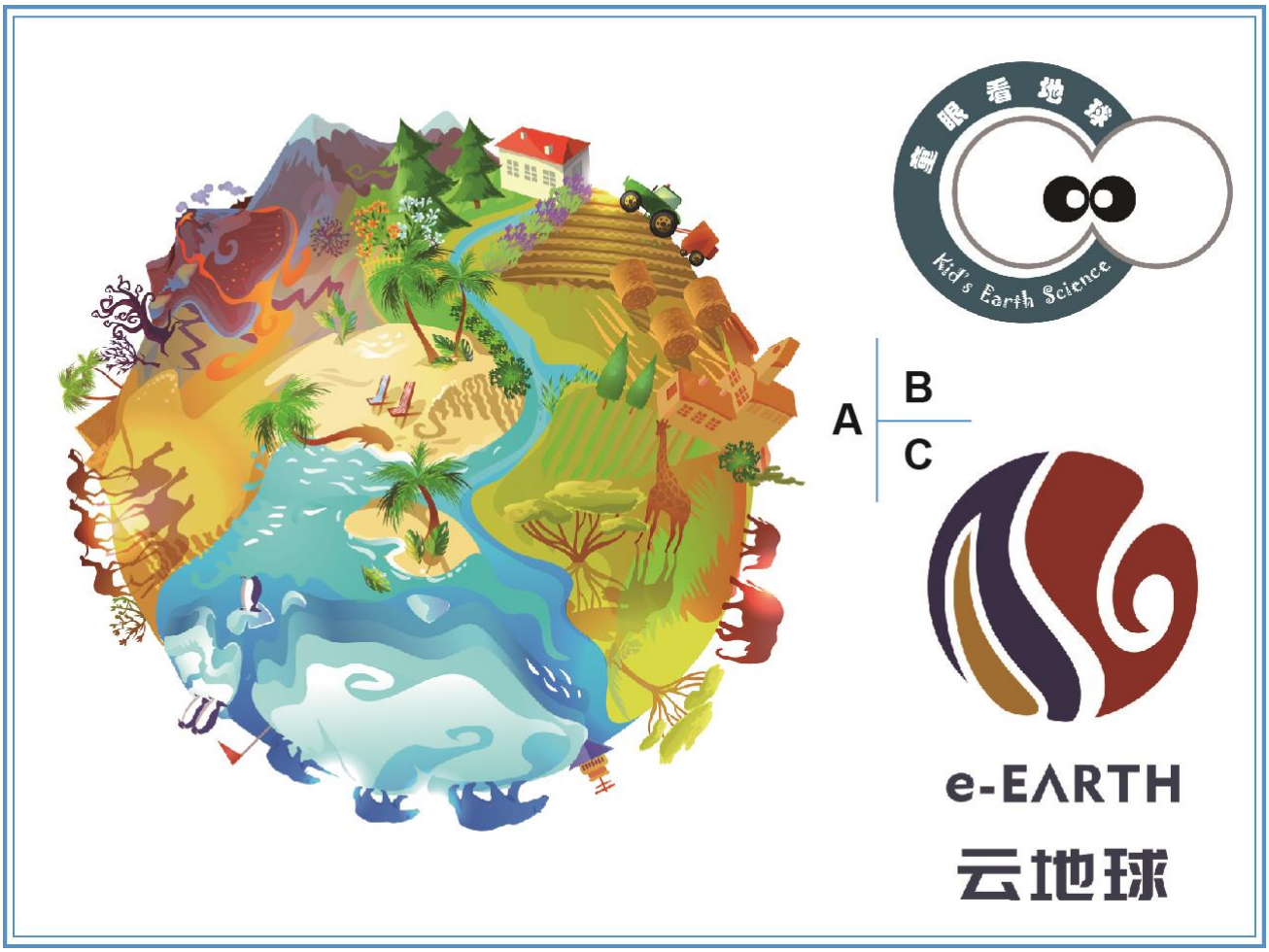

Figure 1. a) The Earth and Earth Science in the eyes of non-specialists (modified after [3]); b) The WeChat official account “Kid’s Earth Science” set up by Aufine International; c) The WeChat official account “e-Earth” set up by the Yunnan Key Laboratory of Earth System Science.

2.2. Geoscience research and education resources of Yunnan

Yunnan is located in southwest China (Figure 2a). From the perspective of Earth science, Yunnan is located in the southeast margin of the Tibetan Plateau, which is a natural extension of the plateau to its southeast. The Tibetan Plateau is the largest and highest plateau on Earth. Its existence has a significant impact on geography, environment, climate and biology at regional and global scales. Because of its location, Yunnan is one of the regions most affected by the uplift of Tibetan Plateau, exhibiting a unique geographical landscape and biodiversity.

The reason why Yunnan has the present appearance is that Yunnan has experienced a long and complex geological evolution history, which is preserved in different geological records, such as fossils and rocks. The “Chengjiang Fauna” in the early Cambrian period (about 540 million years), the

dinosaurs in the Jurassic period (about 180 million years), and the mountains, valleys, rivers and lakes formed in the Cenozoic period (about 65 million years) are all world-class geological records or geographical landscapes. They have become a hot spot for geoscience research, attracting not only global geoscientists, but also tourism enthusiasts around the world.

Also because of its location, Yunnan suffers from severe geo-hazards and enjoys bio-diversity. These topics can not be included in this particular scientific expedition, but it is worth mentioning here for the purpose of understanding the whole picture of Earth science of Yunnan.

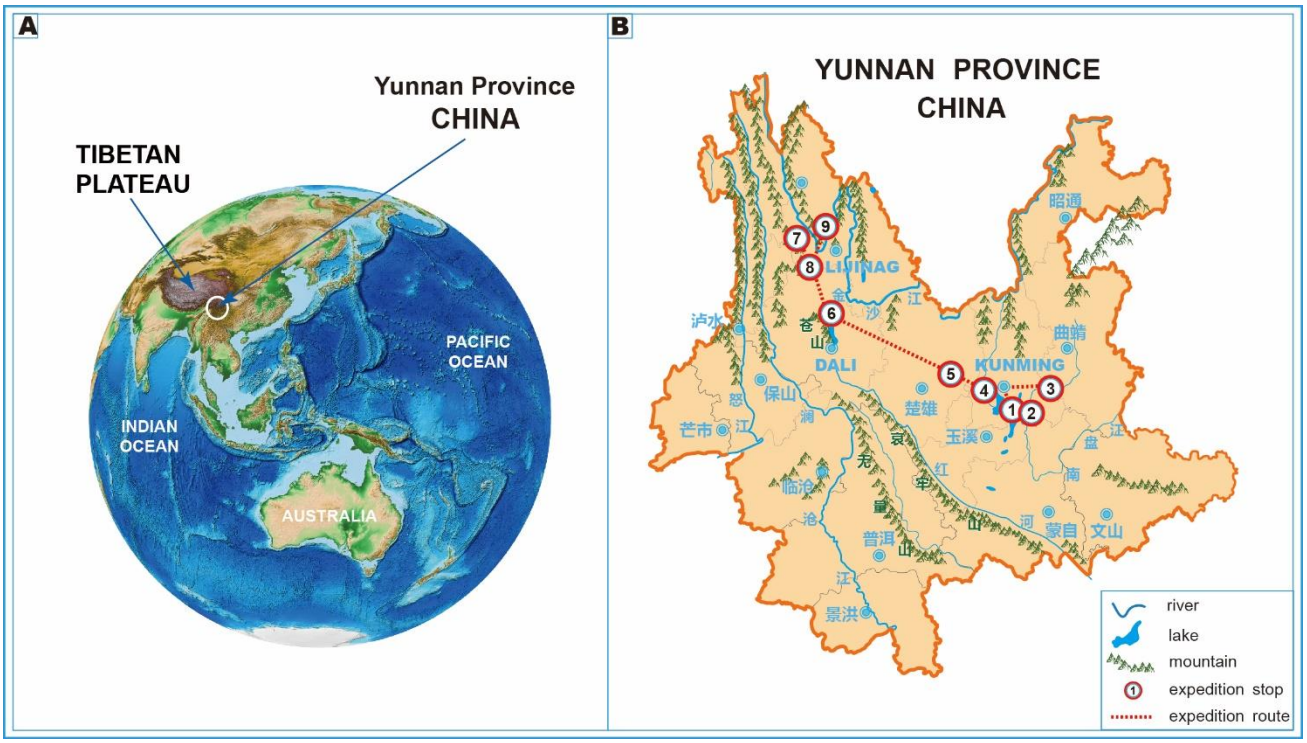

Figure 2. a) The location of Yunnan Province on Earth. Note its relationship with the Tibetan Plateau; b) Landform map of Yunnan Province, in which the YNESE routes and sites are marked.

2.3. A 500-million-year geologic history of Yunnan

The Earth has a history of 4.5 billion years since its birth. In the early days of the birth of the Earth, although there were not many accurate records, scientists speculated that the appearance of the Earth at that time was very different from that of today, which was extremely unsuitable for the existence of life. Until about 3.8 billion years ago, the first life was born in the ocean.

With the continuous evolution of the Earth, such as the formation of continental crust, changes in oceans and compositions of the atmosphere, life was also evolving to higher levels. In the early Cambrian period, about 540 million years ago, life changed dramatically, and the species and shapes of individual living things changed greatly. This is the so-called “Cambrian Life Explosion”. This explosion of life was well recorded in the geologic stratum of Chengjiang, Yunnan (Stop 2 in Figure 2b).

The area where Yunnan is located (South China Block) was in the marine environment for a long time in the Paleozoic Era, especially in the Carboniferous and Permian period. At ~280 million years ago, the shallow sea formed a large area of limestone deposits. Later, due to tectonic movement,

Yunnan region was continuously uplifted and turned into land. Under the surface environments, due to the joint action of rainwater, groundwater and biological activities, the limestone stratum was eroded to form a karst landform, which is most typical in Shilin (Stone Forest), Yunnan, making it a famous "World Natural Heritage" (Stop 3 in Figure 2b).

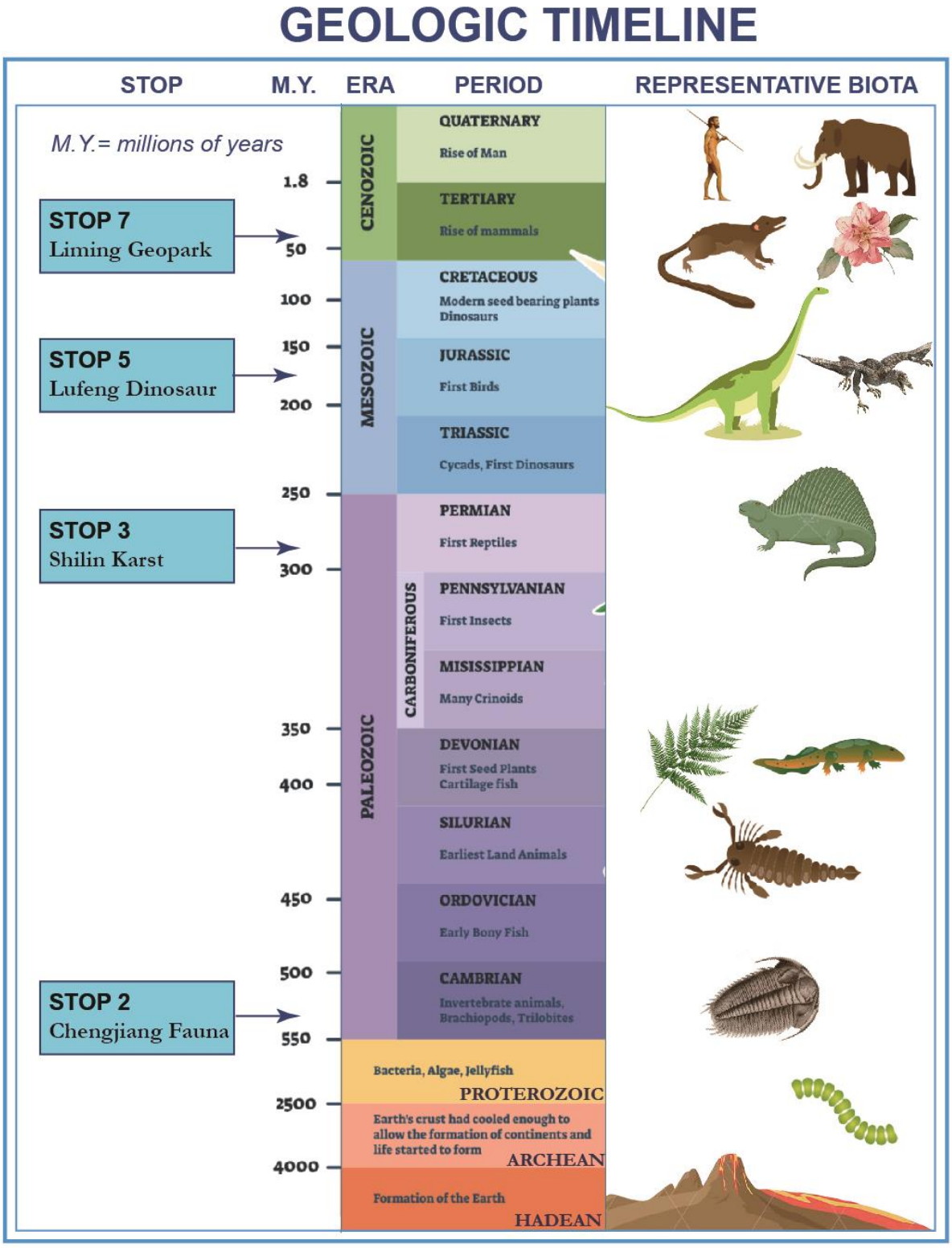

Figure 3. The Earth's evolutionary history and the YNESE Sites.

The Mesozoic Yunnan was completely terrestrial. In the Jurassic period of about 180 million years ago, dinosaurs dominated the world. Lufeng area in Yunnan (Stop 5 in Figure 2b) is the world of dinosaurs. A large number of dinosaur skeletons have been unearthed in the red stratum of this area, making Lufeng a famous dinosaur research base and tourist resort.

The Earth entered the Cenozoic Era, and began with magnificent tectonic movement, climate change and biological evolution. The uplift of the Tibetan Plateau is the most important geological event in this stage. As a result of the uplift of the plateau, Yunnan has formed spectacular landforms, developed large rivers, and gradually formed the Asian monsoon, which has created a variety of geographical environments and nurtured a rich biological ecology. This is the birth of the so-called "Colorful Yunnan" (Stop 7 in Figure 2b).

2.4. The design concept of YNESE

The YNESE places Earth science within the framework of STEM concept. Taking Yunnan's 500-million-year history of Earth evolution as an example, students can review the past, feel the present, and think about ways to solve problems encountered by the Earth in the future. The YNESE focuses on practice, allowing students to walk on the stratum, excavate fossils, identify rocks, observe landforms, feel the ecological environment and experience multi-ethnic cultures. The comprehensive goal of improving scientific quality is achieved by feeling the nature (the Earth), widening the vision, cultivating the interest, exercising the physique and contacting the culture.

3. Introduction to the major YNESE sites

3.1. Planet Earth: a blue life-habitat in the universe

Since human beings flew into space and had the opportunity to see the Earth from space, they have changed their understanding of the Earth that has lived for thousands of years: in the vast universe, the Earth is such a special, wonderful and lucky planet (Figure 4a). Since then, the concept of Planet Earth has been born – human beings have begun to pay collective attention to the fate of the Earth, which is a significant leap compared with the Earth science that had mainly studied the structure and composition of the Earth (Figure 4b) for nearly two centuries. The YNESE therefore started from the Yunnan Solar Observatory of the Chinese Academy of Sciences (Stop 1 in Figure 2) for observing the Sun and the space, allowing students to establish the concept of the universe, solar system and Planet Earth from young ages.

Fuxian Lake Solar Observation Station is located at the north bank of Fuxian Lake (Figure 4c-d), with an altitude of 1720 meters. Fuxian Lake Solar Observation Station is the best telescope platform on the Earth to observe solar eruptions, the best solar observation station in China, the largest ground solar observation base in Asia, and one of the best solar physics observation points in the world. Students can not only observe the Sun through telescopes, but also understand the working principle of astronomical telescopes and listen to the scientific stories of astronomy explained by astronomers.

3.2. The explosion of life on Earth 540 million years ago – Chengjiang Fauna

About 540 million years ago, in the Cambrian period of geological history, a large number of invertebrates suddenly appeared, while in the older strata, few animal fossils were found. Geologists

called this sudden biological event “the Cambrian Explosion of Life”.

One of the representative fossil producing areas of the “Cambrian Life Explosion” is Chengjiang, Yunnan, which is located on the north bank of Fuxian Lake (Figure 5). A large number of biological fossils were found in the Cambrian strata here, which shocked the scientific community and attracted many scientists to carry out research on paleontological evolution [4]. In the past decades, the scientific community has made fruitful achievements in the study of Cambrian fossils, and named the biota represented by the fossils unearthed here as “Chengjiang Fauna”. Chengjiang fossil producing area was officially listed in the World Natural Heritage List, for which the government built a museum (Figure 5).

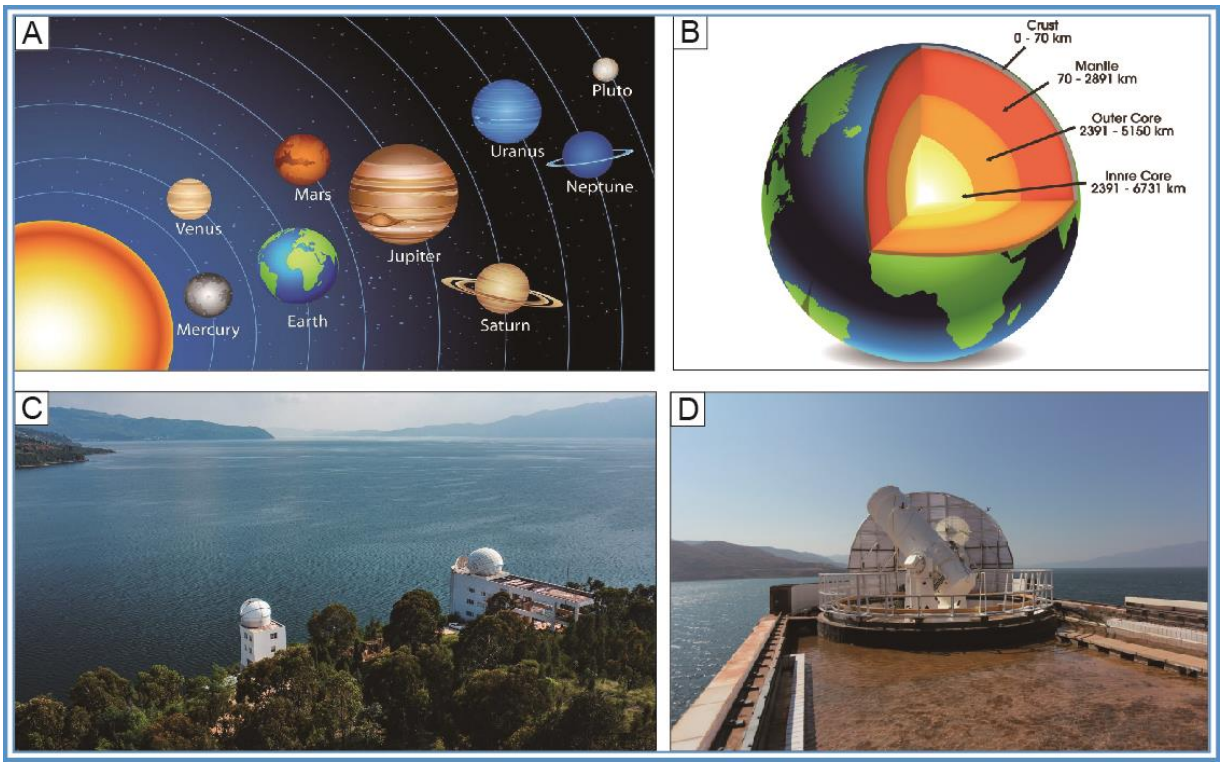

Figure 4. a) Planet Earth in the Solar System; b) Earth and its structure; c-d) Fuxian Lake Solar Observatory of Yunnan Observatory, Chinese Academy of Sciences.

3.3. A mighty ocean 270 million years ago – Shilin (Stone Forest) limestone and karst

Yunnan was located in the South China Block ~270 million years ago, when there was a vast ocean nearby, and carbonate rocks (limestone) were widely deposited in shallow waters (Figure 6a-c). Later, due to the crustal movement, the distribution of sea and land has undergone profound changes. Limestone gradually rose to form a large area of land. Limestone exposed to the sea surface gradually formed a karst landscape through dissolution, erosion and weathering by rain, river water and groundwater.

The most famous karst landscape is located in the Stone Forest of Yunnan Province. It is the only karst landscape scenic spot located in the subtropical plateau area in the world, and also the world’s largest sword shaped karst landscape wonder. It is listed as the World Natural Heritage. At the same time, it has become one of the initial world geological parks and national geological parks (Figure 6a-b)

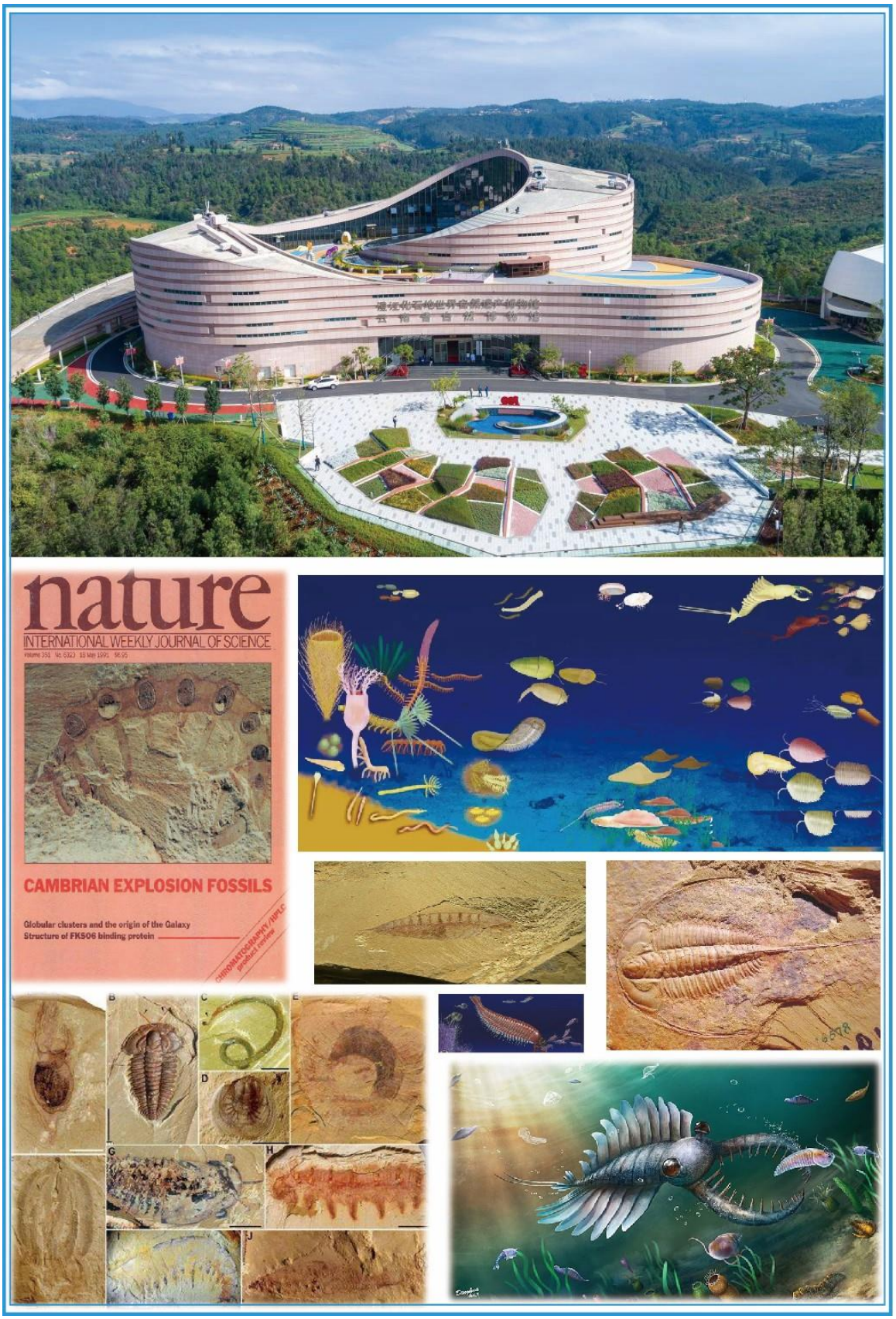

Figure 5. Chengjiang Fauna fossil place (Stop 2 in Figure 2).

Figure 6. Yunnan Shilin (Stone Forrest) National Geological Park (Stop 3 in Figure 2).

The content of the geological investigation in the Stone Forest is not only to visit the karst landscape, but also to understand the rock forming the karst landscape – limestone. Students can use a

hand-held magnifying glass to observe the mineral composition and crystal structure of limestone, granite and sandstone, and use hydrochloric acid to observe the chemical reaction of limestone (Figure 6d-i).

3.4. The Dominator of the Earth 180 million years ago - Lufeng Dinosaur

The Earth had evolved to the Mesozoic era ~180 million years ago, and the land area had been very considerable. At this time, the basic outline of Chinese mainland was established. During this period, the climate gradually became warm and humid, and the land was covered with lush ferns. Abundant food had made the world's most famous generation of dinosaurs rise, and they were almost all over the world. In China, the first complete discovery of dinosaurs was in Dawa Mountain, Lufeng County, Yunnan Province. With the increase of dinosaur skeletons unearthed, Lufeng has gradually become a hot spot for dinosaur research.

Students not only observe the dinosaur fossils, but also have a chance to work on the geologic strata to excavate the fossils by themselves (Figure 7).

3.5. The making of the 'Colorful Yunnan' in the Cenozoic Era – Laojunshan National Geopark

The Cenozoic is the latest geological age in the Earth's history, which began 65 million years ago. The Earth in the Cenozoic era has undergone significant changes: strong plate tectonic movement, the uplift of mountains and plateaus (for example, the Alps-Himalayas), ocean and land changes, the occurrence of the global ice age, the emergence of human beings, and the Earth has gradually become what it is today.

One of the most important geological events of the Cenozoic is the formation and uplift of the Tibetan Plateau (Figure 2a), which has greatly changed the surface geomorphology, with the development of large rivers and the formation of the Asian monsoon climate. As Yunnan is located at the southeast edge of the Tibetan Plateau (Figure 2a), the rise of the Plateau has also greatly changed the face of Yunnan: the rise of the Yunnan Plateau, the formation of mountains and valleys, the development of three parallel rivers, the development of biodiversity, early human habitat, the emergence of modern humans, and the breeding of multi-ethnic culture here, which is the birth of the so-called "Colorful Yunnan". One of the best areas to observe these geological events is Laojunshan National Geological Park, which is located in Yulong Naxi Autonomous County, Lijiang City, Yunnan Province (Figure 2b). The main geological relic is the alpine Danxia landform (Figure 8).

The route of the scientific expedition starts from Liming Town (Figure 8a), which is the core area of Laojunshan National Geopark. The houses and roads of the whole village are made of red sandstone. It is a multi-ethnic residential area, including Lisu, Naxi, Bai and Han.

Climbing up the steep mountain road, we can see layers of red rocks, including mudstone, sandstone and conglomerate, which are like a historical scroll, recording the evolution history of the Earth frame by frame (Figure 8b). At the earliest stage of the Cenozoic era, the altitude here was not high, the climate was dry, and even the desert was sparsely populated with plants. The rivers were not what they are now. The first peak we reached was the highest peak of Thousand-Turtle Mountain (Figure 8c-g), with an altitude of 2800 m. With the uplift of the Tibetan Plateau, the natural geographical environment here has undergone significant changes. The altitude is rising continuously (the Yunnan Plateau is rising continuously). The climate has changed from an arid desert (Figure 8h)

to a humid monsoon. Vegetation has begun to flourish; rivers have been reorganized; the formation of the First Bend of the Yangtze River (Figure 8i) signaled the birth of the modern Yangtze River [5,6]. Today, the bronze statue of Xu Xiake (Figure 8j) stands in the First Bend of the Yangtze River to commemorate the Ming Dynasty geographer's visit to the Jinsha River ~400 years ago.

Figure 7. Yunnan Lufeng Dinosaur Valley and Dinosaur Museum (Stop 5 in Figure 2)

Figure 8. Yunnan Laojunshan National Geological Park and the First Bend of the Yangtze River (Stops 7-8 in Figure 2).

4. YNESE and the STEM concept

The YNEES ended in Lijiang (Figure 9a-b). At the closing ceremony, students and parents shared their experience of the investigation. They all agreed that the expedition was great success in promoting STERM education (Figure 9c-e), integrating scientific theory, practice, instrument experience, history review and vision, and physical exercise, and national culture experience.

Figure 9. Graduation ceremony of the YNESE.

In order to explore teaching methods and facilitate experience exchange, this scientific expedition also employs a team of professional photographers to record the precious moments the students and parents experienced during the entire journey, with a printed team report of the expedition, a graduation certificate, and a personalized album for each family (Figure 9f-g).

5. Conclusions

There is no doubt that the concept of STEM education is the new demand for education raised by the development of contemporary society and the new trend of modern education. However, it should also be noted that the promotion of STEM education concept and its implementation in society is a continual process. As far as the current reality is concerned, the understanding of STEM education by schools, students and parents is still at the primary stage, even unfamiliar. This geoscience scientific expedition in Yunnan has made a new cognitive and ideological impact for parents and students. At the graduation ceremony, students and parents said that this scientific expedition had a significant influence on student's scientific comprehension from the design concept to the organization and implementation, which cannot be learned from any STEM-related disciplinary classroom in schools. From the perspective of Earth science, STEM education needs to start from primary schools and junior high schools, and continue to senior high schools and universities. In this process, we need to pay attention to appropriate teaching methods to achieve the best engaged learning outcomes. For example, field training and practical training in Earth science are the distinctive characteristics of this discipline. Such natural orientated approach should be not only required for STEM education, but also adapted to the development of a sustainable future of the modern society.

Acknowledgments

Thank Zixuan Bian, Zhushan Wang and Peiling Feng of Yunnan University for their help in the field. Thank Junkai Zhang and Jiukun Yan Du for photographing during the scientific expedition. Thanks also go to the reviewers for their constructive comments on this report.

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Author's biography

Dr. Hongbo Zheng is a Professor and Director of Yunnan Province Key Laboratory of Earth System Sciences at Yunnan University, China, and an Honorary Professor of School of Earth and Environmental Sciences at Queensland University. He is a specialist in the study of Earth history, and has carried out extensive research in the southeastern margin of Tibetan Plateau, including Yunnan Province, China.

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