Natural History and Natural Resources Through the Earth Sciences in Modern China After 1900

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This book first published 2024

Ethics International Press Ltd, UK

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

Print Book ISBN: 978-1-80441-815-4

eBook ISBN: 978-1-80441-816-1

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Dedicated to the memory of Amadeus William Grabau (1870 – 1946), whose career as a professor at Peking University resulted in the first professional class of paleontologists in China and whose scholarly work gave the rest of the world new insights on changes in sea level through geologic time in the context of continental drift.

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Preface: On the Initiation of a Sinophile

The economies of the United States of America and the Peoples Republic of China are powerful competitors rated as the top two on the global stage. Nominally the two countries are said to account for 42% of the world's Gross Domestic Product (GDP). This book examines the geology behind geopolitics and attempts to show how the pursuit of natural science and natural resources so basic to the earth sciences are intertwined. Published in 1852, the United States federal government entered this realm with its first large-scale, professionally-orchestrated *Report of a Geological Survey of Wisconsin, Iowa, and Minnesota*. Lavishly illustrated, the report not only provided a comprehensive treatment of the district's natural history including the use of fossils to distinguish different rock units, but also an evaluation of the region's mineral resources. Most notably, such coverage dealt with the lead-mining area in the upper Mississippi valley in today's tri-state area of Iowa, Illinois, and Wisconsin. Built against a limestone bluff in that region, an interior kitchen door in the home where I grew up opened to a tunnel excavated to reach veins of lead ore buried in the adjoining hillside.

Many American states already funded independent surveys prior to the mid-nineteenth century (CE), but the involvement of the federal government set a higher standard that preceded comparable efforts in mainland China by nearly a century. The chapters in this book feature maps for provinces in mainland China as well as Taiwan together with a selection of black and white photos culled mostly from the author's travels beginning in 1983. Tracing the importance of the earth sciences back to the beginning of a modern China in 1900, the book's scope is enlarged to show the influence of earlier visitors, most of whom worked with their Chinese counterparts to establish a strong foundation for expansion of the earth sciences in China.

Opportunities were scarce during the 1950s and 1960s for a young person growin g up in the American Midwest to be influenced by or attracted to much of anything related to China. During the Cold War between the United States and the Second World, much of anything pertaining to faraway China was held in abeyance, if not willfully shut out by the general public striving to achieve the American Dream. Digging into a sand bar on the Mississippi River at play during an outing, adults might say that a youngster was excavating a hole deep enough to reach China. Leaving food on the plate at the dinner table, a mother might offer a reprimand in reference to starving children in China.

Speaking of food, the culinary repertoire of a mid-western household was largely sustained by a diet of meat and potatoes with a side of corn on the cob. The only Chinese food that I recall from my childhood was a dish called Chop Suey, which consisted of diced chicken in a mildly sweet-and-sour sauce served over rice and sprinkled with crunchy string noodles. The meal had no roots in genuine Chinese cuisine, but was concocted or at least popularized by the likes of a fictional housewife called Betty Croker who marketed processed foods for corporate America. How, then, was a person coming from such a background to form sympathies for or perhaps even an admiration for things related to the Chinese people, their language, long history, high culture, and refined cuisine? In short, how does a Sinophile immerge from a place so wrapped in itself and comfortably removed from the rest of the world? Yet, individuals from earlier generations coming from the American heartland with backgrounds in engineering, natural history, and geology found their way to China as early as 1900.

References to China were there in the background. Who hadn't heard about Marco Polo and his travels from Europe to Old Cathay in the late thirteenth century (CE), then ruled by the Kublai Khan – grandson of the infamous Genghis Khan? The young Venetian's account of the silk-manufacturing city of Suzhou with its network of canals and stone bridges is charming, a place that remains intact at its core today. My family was home-bound in its habits and rarely traveled far away. How could I dare to imagine that I might someday visit the very chapel in Venice where the Polo family worshiped, as well as the canals of Suzhou where Marco set foot far from home? Even so, my mother engaged in bed-time reading for her sons and a book I distinctly remember was Pearl Buck's *The Good Earth*. The work ethic of the main characters, peasant farmer Wang Lung and his wife O-lan, made a strong impression. I was a boy from a river town, but grew up on a plot of land with an apple orchard and rich, black soil intensely cultivated for vegetables. My elder brother made a point of letting me know that he would inherit the land after our parents and that it was something never to be sold at any price. The lesson was not lost on us, that Wang Lung's foolish sons were spoiled by material riches and were doomed to sacrifice the true source of their wealth by selling the land. The book was a best-seller and the author, who had grown up in China as the daughter of missionaries, became in 1938 the first American woman to be awarded the Nobel Prize in Literature.

Other inducements to learn about China might have come from relatives or neighbors who lived or worked in that part of the world prior to the Second World War. Later, I became aware of individuals who either served as missionaries in China or as aviators fighting along-side the Chinese against the Japanese in the prelude to America's entry to the war after the attack on Hawaii's Pearl Harbor in December 1941. Earlier that year, 99 pilots and a support group of some 200 civilians were recruited by the Chinese Nationalist government to join the American Volunteer Group, which became famous as the Flying Tigers operating from air bases in south China. Following my first experience in China as an adult in 1983, I quizzed my aunts and uncles about their awareness of the Sino-Japanese War that began in 1937. American newspapers reported on the spark outside Peking that led to full-scale war on the Asian continent, but my relatives were oblivious to those early stirrings of a world-wide conflagration. They were young and life for them in the American Midwest was on the cusp of recovery from a deep economic depression.

A direct dive into China's culture and history would have required classroom exposure to an American expert on those topics, an opportunity that never occurred to me as a college student in the late 1960s. Initiation as a Sinophile would need to happen through the back door, fittingly in Chinese the acquisition of a thing by *guan-xi*. My personal back-door entry to China was actually out my front door, where I made the discovery of rocks and fossils as a youngster. I was drawn to a construction site, where workmen using explosives and heavy equipment blasted a new roadway through the side of a hill. The place was abandoned at the end of each workday and I was free to explore on my own. When I began to find the fossils of marine animals with shells crowded together in lime-rich rocks, the disparity between past and present worlds was perplexing. "What are they," I asked my father, handing him a pocket-full of fossils I had picked from the rubble. He had taken a geology course during his university studies and explained to me that our home was once part of a vast salt-water sea that covered much of North America.

Afterwards, my father organized a visit to the Field Museum of Natural History in Chicago, where I viewed dinosaur skeletons for the first time. When I announced that I wished to become a paleontologist, he responded by saying that it would be difficult for me to earn a living that way. "You might do it," he said, "if you study hard and become a college professor." Two things took ahold of my consciousness with a firmness unlike nothing else. The first was the notion that almost an entire continent might be flooded by seawater. No more than a stone's throw from my home, a crack had been pried open in the ground to expose rocks and fossils some 450 million years old. I fell into that chasm and was transported to another world that existed long ago, when sea-level was a good deal higher than today and must have flooded other continents around the world at the same time. How could that have happened? Why did the waters recede and under what circumstances could such a startling transformation reoccur?

The other obsession to take hold was the naïve idea that I might continue to study fossils while earning a livelihood as a college professor. Little did I know at that time, how a Chinese paleontologist had become one of the leading authorities on the same marine fossils I collected from exposures near the Mississippi River or how Chicago's Field Museum might play a role in my future advancement as a graduate student. Places deep in the interior of China must have been flooded by seawater at a time coeval with the rocks and fossils from Iowa that I was learning about during my boyhood, then as a college student in the late 1960s, and thereafter as a graduate student in Chicago in the mid-1970s.

Meanwhile, relations remained poisonous between the People's Republic of China and the United States after conclusion of the 1949 revolution. I recall some of the bombastic name-calling quoted from the other side in our local newspaper. Americans were labeled as "yellow running dogs." From the American side, there was acrimony over who, exactly, was responsible for "losing China." Hostilities continued right through the years that the United States sent soldiers to Vietnam. Later, a Chinese paleontologist who became a professor at a Canadian university admitted to me that my surname, a name shared with President Lyndon Johnson, was one that caused revulsion when he was a boy growing up in China. Various delegations arriving in China from American and western agencies like the International Union of Geological Sciences were beginning to report back with the names and research interests of individuals actively working in that country. A whole new generation of Chinese scientists had grown up and assumed research roles since 1949, few of whom were known outside China. It was hoped that professional contacts might be made with Chinese geologists and paleontologists in the expectation of possible joint projects. In 1977, I finished my studies at the University of Chicago and took a position as an assistant professor at Williams College in western Massachusetts.

Later in 1979, I scoured a list of Chinese paleontologists brought back to the United States by a visiting delegation and circulated as public information. I chose two names from the list, which included mailing addresses. One was for a paleontologist working in Beijing (north capital), where the communists re-established the seat of national government previously maintained by the Qing Dynasty until 1911. The other was for a paleontologist from Nanjing (south capital), where the Nationalist government had run the country. The most enthusiastic response to my inquiry came back from Nanjing. Knowing that I would soon qualify for a year's sabbatical awarded to junior faculty, I laid plans for an ambitious project bringing me both to Europe and to China for field studies and fresh research related to our planet's complicated history of ancient sea-level changes.

The intent of this book is to offer a memoir free of the technical jargon applied to obscure geological concepts, but more to convey the personal experiences accumulated over decades of repeated visits to China, during which interactions with Chinese colleagues allowed me to travel widely and experience profound changes in the lives of its citizens. The actual rocks and fossils related to my interests remain in the background with the details mostly limited to footnotes where crucial documentation is provided. That said, China is a big land where big changes in how the earth's long history is interpreted are constantly revealed through new discoveries of extraordinary fossils such as the oldest fish and the emergence of feathered dinosaurs. Some of that excitement is portrayed in this book, although the principal emphasis is on day-to-day observations made at intervals over time to mark changes in the way ordinary people lead their lives in the world's most populous country. The core fabric of this account explores a world parallel to cherished American concepts that include notions about achieving the Chinese Dream and the possible role that Chinese Exceptionalism might play in that pursuit. Both in the West and the East, there exist an undertone of ethics in the balance of the pure and applied earth sciences that influences how a society seeks to manage its economy in the wider world. That balance has deep roots in history as competitive societies seek ever more raw resources to power their home industries.

I am proud to proclaim myself a Sinophile. My life is immeasurable enriched through experiences visiting China over the span of several decades as well as a vicarious exposure to the recorded experiences of earlier visitors interested in the promotion of science and natural history during the years soon after the turn of the Twentieth Century (CE) and the emergence of a modern China. These insights not only reflect my personal gratification, but are offered in the certain knowledge that the dramatic changes now occurring in mainland China and Taiwan, both for good and for ill, are certain to have a dramatic impact on life everywhere else around the world in the context of evolving geopolitics.

Acknowledgements

Foremost, I am indebted to the Committee on Scholarly Communication with the People's Republic of China through the US National Academy of Sciences for funding my initial foray to mainland China in 1983. That award brought me to the Nanjing Institute of Geology and Palaeontology to launch a research program with Professor Rong Jia-yu. Our first contact occurred the previous year in Oslo, Norway, during a field meeting of the Subcommission on Silurian Stratigraphy (SSS) a unit of the parent Commission on Stratigraphy under the International Union of Geological Sciences (IUGS) through the United Nations Educational, Scientific, and Cultural Organization (UNESCO). Lasting 25 million years, the Silurian Period is one of the several divisions in geologic time during the Paleozoic Era. The IUGS maintains active working commissions to strengthen international communications in regard to all of the time periods in the geologic time scale. I had served as a conference organizer for the Oslo meeting during a sabbatical from Williams College. The years 1982 and 1983 proved to be among the most formative in my subsequent career as a geologist and paleontologist. Professor Rong also visited Williams College from March to July in 1987, during which field excursions were undertaken to several regions in the midwestern part of the United States and Canada. Ongoing traffic between the United States and mainland China was made possible by grants from the National Academy of Sciences (1986), US National Science Foundation (1995), National Geographic Society (2009), and the Marion and Jasper Whiting Foundation (2009). In 1992, I was elected to the SSS chairmanship and served in that capacity until 2000, when Professor Rong took over the chairmanship until 2008.

Field meetings arranged by the SSS in Estonia (1990), Czechoslovakia (1992), Austria (1994), Australia (1986), England (1989), New York State (1996), Spain (1998), again Australia (2000), Sweden (2005), China (2007), and Sardinia (2009) allowed regular contacts between myself and my Chinese colleague. I was the principal organizer of the 1996 Rochester symposium in New York State during my tenure as SSS Chairman and Professor Rong was the principal organizer of the 2007 Yangtse symposium in Nanjing during his subsequent tenure. These several field meetings and symposia promoted major advances in the definition of time units as well as the free exchange of ideas about paleogeography and concepts like global changes in sea level. Support from the Office of the President and Office of the Dean of Faculty at Williams College was instrumental in making my participation possible in many such conferences.

Besides Professor Rong, other individuals made critical contributions leading to the compilation of this volume on natural history and natural resources that accompanied profound changes in China's society since the dawn its modern era in 1900. Among those to whom I am most grateful is Li Wen-guo, field geologist with the Inner Mongolian Geological Survey, who served as our guide during the 1999 expedition (Chapter 6). Geologist Su Wen-bo also worked diligently to assure smooth connections regarding all arrangements for the group's travel and accommodations during that excursion. Our friend, Zeng Jie, took time to tell me about her education at Sun Yat-sen University in Guangzhou during the 1980s (Chapter 9) as well has her work as an English translator assisting foreign visitors to the oil fields in China's western province of Xinjiang. There she met her future Norwegian husband and later entered a different world living as Angie Bockelie in Oslo. Due to sensitive issues discussed with colleagues and other experiences in Guangzhou that left deep impressions, the names of individuals have been altered to protect their identities (also Chapter 9). Professors Su Shew-Jiuan and Lin Tsung-Yi, from the Department of Geography at the National Taiwan Normal University in Taipei, were our hosts in Taiwan, who helped with travel arrangements and contacts at some of the island's spectacular geoparks (Chapter 10).

Alan Mazur at Syracuse University was the source of valuable background information on the life and career of Amadeus William Grabau (Chapter 3), as well as family documents and photos. Sylvia Brown, archivist with the Williamsiana Collections at my home institution of Williams College, provided advice and access to the Sara Clap Goodrich letters describing conditions in the besieged Peking Legation Quarter during the Boxer Rebellion (Chapter 2). Likewise, Colin Torre, archivist at the Clark Art Institute in Williamstown, Massachusetts, provided documents and advice regarding the career of Robert Sterling Clark during his early years in China (also Chapter 2).

Finally, deepest thanks go to my spouse B. Gudveig Baarli, who shared with me many experiences in mainland China from 1999 onward, including all the planning for our extensive travels in Taiwan in 2023. Her many contributions include near constant advice on computer drafting of maps and manipulation of photographs, as well as general advice and support as a fellow geologist during the writing of this volume.

Chapter 1

China's Geology Meets the World: A Purview in the Library Stacks

In the case of Geology.... many scientific questions and learned-sounding classifications, which at first sight appear to involve considerations of an abstract nature alone, do, in fact lead to the solution of most practical and profitable problems.

David Dale Owen, *Geological Reconnoisance State of Indiana* (1832)

The land area of continental United States (including Alaska) and today's mainland China is close to parity, with a difference of only 77,775 square miles (201,435 km^2) favoring America. However, the style and level of competency involved in ground surveys to establish the natural resources and geologic history of China followed behind the earliest efforts to do so in the United States as first launched in the 1830s. The delay is related to how scholarly work was perceived in the two counties and how rapidly science was recognized as a useful handmaiden to economic progress. Although the imperial examinations that began under the Sui Dynasty (581 to 618 CE) functioned as a national system for the selection of civil servants, none of the natural sciences was covered by the exams and, thus the exploitation of natural resources advanced in an unorganized and arbitrary way. It was only during the earlier years of the Republic of China in 1913 that the Geological Survey of China was established. The survey benefited through the simultaneous founding of a short-lived Geological Research Institute in Peking (Beijing), which graduated a single class of students who staffed survey teams producing the first geological maps for provinces in the eastern part of the country.[1] In addition to its own natural resources, China's cultural treasures include landscapes of extraordinary scenic value, only belatedly enshrined in natural parks that exhibit geological interpretations for the enrichment of its citizens and those visiting from abroad. How did the use of these riches unfold through exploration?

As a subdiscipline, stratigraphy is unusually bookish in the sense that rock layers (formed mostly by accumulated sediment) are like the pages of a book that appear in order from oldest to youngest to reveal a recorded history in any single place across millions of years. Historical geology is an allied topic, often taught as an introductory college course in the geosciences. It is a course that fell to my responsibilities during a long teaching career. The fundamentals of historical geology depend chiefly on advanced studies in stratigraphy, which also became my duty to teach for students completing the geology major. When going to the countryside for fieldwork, it became my habit to find the full range of publications written by any predecessors who explored that particular piece of ground.

Initiation of Federal Survey Work in the United States

That's how I came to appreciate David Dale Owen, an immigrant from Scotland to the United States in 1827, who until his death in 1860 authored an astonishing number of reports on the geology of several states throughout the American Midwest, some still territories without a functional state government at the time. Trained as a medical doctor but with a background in chemistry and mineralogy, David Dale Owen was the son of Robert Own, a wealthy industrialist with a socialist background who invested in the communitarian experiment at New Harmony in southern Indiana during the early 1800s. The social experiment was a failure, but New Harmony became the headquarters for the son's extensive geological surveys that were organized to methodically cover an immense area within the watersheds draining the Ohio, Mississippi, and Missouri rivers. The young Owen was influenced by his father's social ethics, in that science was perceived as the rightful path forward to bring the benefits of industry and commerce to the people living in a given place. In so far as possible in newly surveyed regions, fossils became the key to sort out the age and correlation of rock layers spread over a vast region. Hence, Owen widened his expertise to include the study of paleontology and he became an early authority on fossils from the American Midwest.

Moreover, David Dale Owen was a talented landscape artist, who provided many of the illustrations accompanying his reports. His rendering of the bluffs along the upper Mississippi River (Fig. 1.1) depicts Ordovician dolostone layers as they appeared around 1839 in eastern Iowa, where I grew up a century and a half later and frequented the same spots. Drawings of fossils typical for those rocks were included in his reports and formed the baseline for all other studies that followed afterward. Among other things, the bluffs between Iowa and northern Illinois were notable for their mineral wealth, which included ores of lead (galena) and zinc (sphalerite). Between 1830 and 1860, geological surveys comparable to Owen's 1839 report grew to 56 in number and addressed resources within 33 different states or federal territories.[2] The ultimate example of professionalism during this period came with Owen's federal report on the geology of Wisconsin, Iowa, and Minnesota published in 1852. This kind of work by survey teams in the United States set an early standard for the two Dionysian faces of geology. These are represented by the extractive sciences related to industry, which in extreme practice ends with environmental degradation. On the other hand, the purely academic advancement of a fossil-based time scale for correlation from one region to another provides new insights on our planet's development through time.

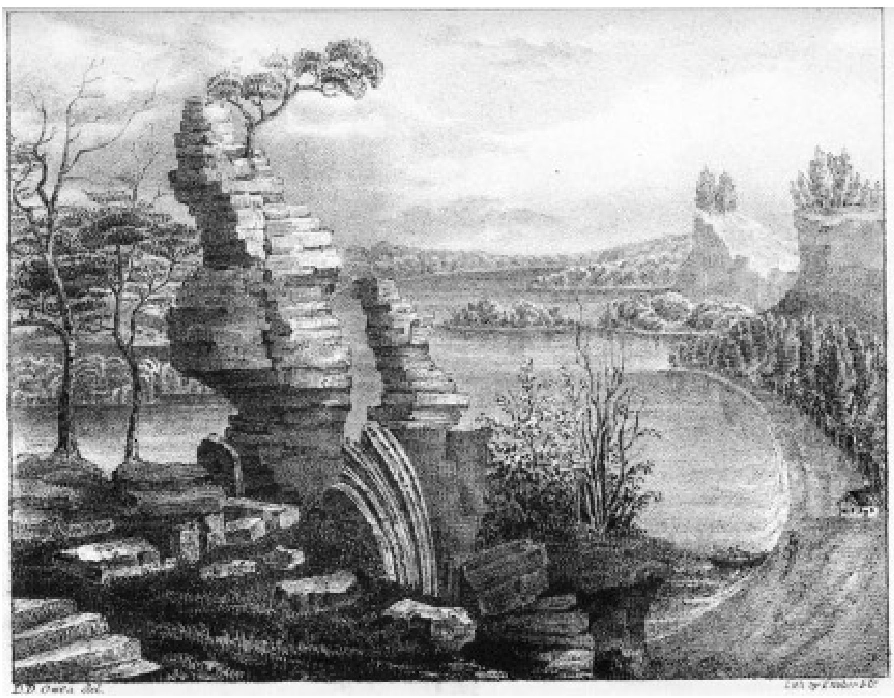

Figure 1.1 *Bluffs along the upper Mississippi River in today's eastern Iowa from an original drawing by David Dale Owen published in 1839.*

Pre-1900 Status of Geology and Natural History Work in China

Delay in development of an organized system of geological survey work in China was due to Chinese scholars who by tradition avoided any of the natural sciences that required field labor. Exceptions are few but notable. A clear understanding of objects perceived as fossils in the context of the rock layers in which they are buried is attributed to the scholar Li Tao-Yuan, who in 500 CE described Stone-Fish Mountain in Hunan Provence in his treatise "Through the Water Ways".[3] A riverine setting is central to the scholar's work, in this case the Yangtze River, which is Asia's longest and flows from deep within the Chinese mainland. Artistic renderings, especially of the famous gorges on the upper Yangtze River (Fig. 1.2), capture a realistic beauty parallel to David Dale Owen's landscapes drawn for a more science-oriented audience. Whereas the description of fossils was routine in Owen's scholarship, an understanding of such natural artifacts took longer to reach scientific literacy in China despite earlier clues.

Figure 1.2 *Deep gorge in the upper Yangtze River on the border between China's Sichuan and Hubei provinces (author's collection from an unknown artist).*

Even so, the importance of natural resources connected with industrial and medicinal products has a long history in China closely related to its culture. Exquisite bronze jars, drinking vessels, and alter pieces from the Shang and Zhou dynasties date back 1,600 years prior to the Common Era. Chinese prospectors from those times had to find naturally occurring ores of copper and tin in order for bonze metallurgy to blossom. Carvings in jade have an even older pedigree dating to 5,000 BCE and grew to hold a highly valued place in Chinese culture symbolizing virtues of goodness, wisdom, and purity. By the time of the Shang Dynasty, ritual jade carvings were acquired as valued symbols of rank, as were ceremonial blades and axes that signified the owner's high status. The raw material called jadeite derives from metamorphic processes of extreme sub-surface heat and pressure. The rocks may be mined in mountain belts, but also occur as eroded materials washed into river beds far from their original source, as was the case for deposits accumulating in the lower Yangtze basin.

A peculiar example of mineral economy associated with Chinese culture has to do with applications of quicksilver, or mercury (*shui yin* in Chinese), as a palliative against skin disease and preservative in preparations of the deceased for burial. The ore of mercury is cinnabar, a sulfide mineral (HgS) with a distinctive brick-red color and a high density that exceeds that of lead (galena). Cinnabar also was commonly sourced to make a brilliant red pigment. Extraordinary evidence for the use of quicksilver is related to the burial tomb of Emperor Quin Shi Huangdi outside the city of Xi'an in Shaanxi Province. The emperor who united China at the end of the Waring States Period in 221 BCE, is most renowned today for the archaeological discovery of his buried army of thousands of life-sized warriors modeled in clay. His separate burial mound at Li Shan has yet to be excavated, but the Chinese historian Sima Quian, who wrote an account a century after the emperor's death, claimed the burial site included a model of China's geography complete with lakes and rivers of shining mercury. Chemical soil tests taken from borings into the burial mound indicate that levels of mercury contamination are from one to two levels of magnitude above normal compared to the surrounding area.[4] Ancient mines for cinnabar are known from Xunyang in southern Shaanxi Province, attesting to the fact that Chinese prospectors were familiar with the ore of quicksilver and actively searched for it.

Role of Chinese Porcelain in International Trade

The oldest Chinese porcelain is dated to the Shang Dynasty after 1600 BCE. The level of perfection known as hard-paste porcelain is associated with the Yuan Dynasty between 1279 and 1368 CE. The essential raw ingredient of porcelain is kaolin, which occurs as a clay mineral rich in aluminum and silica derived from the chemical weathering of rocks like granite in a warm, wet climate. The term comes from the Chinese word *gaoling*, meaning "high ridge" for a locality near the present-day city of Jingdezhen in Jiangzi Province. The word first entered western languages in 1727 from the transliteration to kaolin by visiting French Jesuits who returned from China. The clay mineral occurs more widely, of course, but Chinese prospectors had to know what to look for in order to support the porcelain industry. The blue on white enamel glaze characteristic of porcelain from the Ming Dynasty in the fourteenth and fifteen centuries depends on the mineral cobalt, which Chinese prospectors also had to recognize and know how to find in nature.

Widespread export of Ming porcelain to Europe was facilitated by trade with Portugal, Spain, and especially The Netherlands through the Dutch East India Company, which operated from 1602 until 1799 as the world's largest and most profitable trading company. Among other lucrative products that flooded into Europe were spices from Indonesia and tea from India, but the company also imported thousands of high-quality Ming vases, bowls, plates, cups, and tea pots. Due to the high value of Ming porcelain, domestic producers became interested in joining the market. This resulted in knock-offs such as Delftware manufactured principally in and around the Dutch city of Delft. To succeed, however, the process of firing hard-paste porcelain had to be re-discovered by trial and error and supply chains for kaolin and cobalt had to be established independently. Not long after the technical term for kaolin was introduced in the west, a major new source for the clay was discovered in 1747 in Cornwall at Tregonning Hill.

Monopolies set up for porcelain production in other countries soon entered the market. The trademark held by Royal Copenhagen is a good example, established in 1775 as the official supplier to the Danish crown. The cobalt necessary for finishing the characteristic blue patterns on white enamel was mined in Norway at the Blåfargeverk in Modum. Royal Copenhagen remains in business today, supplying popular tableware with a classic

Ming look, although supplanted by design patterns of a wholly Scandinavian origin. In contrast, the trade mark for Royal Willow Ware was produced in England by a company founded in 1779 by Thomas Turner. The motifs for this widely imitated blue-on-white tableware stuck to oriental themes that incorporated pavilions set in lakeside gardens surrounded by willow trees. Essentially, the high artistry of the Ming Dynasty set off a parallel industry in Europe that aimed to replicate the standards of Chinese porcelain manufacture with an independent supply chain of raw materials.

Attempts to Promote Industrial Expansion in China

As late as 1900, the succeeding Qing Dynasty failed to capitalize on industrial expansion at a level commensurate with western investments. Kang You-wei was a well-positioned aspirant from Guangzhou with a traditional background in Confucian scholarship who prepared for the grueling nation-wide examinations that served as the portal for civil service in China's imperial bureaucracy. Not only did he pass his exams in Peking in 1895, but immediately submitted a plan for the top-down modernization of China through its state offices. His efforts slowly passed through official channels until he was granted a personal audience with Emperor Guangxu at the Summer Palace in June 1898. Among the many reforms in Kang's petition was the urgent need for China to exploit its own strategic resources, including copper ore from Yunnan, coal and iron ore from Shanxi and Guizhou, lead ore from Shandong and Hubei, and tin ore from Jiangzi and Hunan.[5] It was argued that foreign investors were bound to do so, if such resources were not more fully developed under direct state control. The plea arrived too late for the times.

China's Modern Industrial Base

Examples based on Chinese cultural artifacts related to the mining of copper, tin, jade, cinnabar, and kaolin in antiquity pale by comparison with the thirst of China's modern economy for comedies necessary for heavy industry. In 2021, China was responsible for 56.7% of global steel production and 41% of refined copper, as well as other important metals.[6] More than half of the iron ore funneled into the modern Chinese steel industry is imported from Australia and this imbalance threatens the stability of the country's economic engine. Pressure on China's oil industry to expand domestic sources also is intense, with ongoing exploration concentrated in far western Xinjaing Province and offshore in the South China Sea. China has long maintained its dominion over small islands throughout this region, some of which are contested by other countries such as Vietnam and the Philippines. More mundane in technical aspects, but equally important in the Chinese economy is the use of limestone in making concrete. Road surfacing, building construction, and the pilons needed to support an extensive and growing network of elevated train lines all depend on a massive supply system for concrete products.

Both in China and the United States as well as most other countries around the world, the modern state employs experts trained in geology to survey natural resources and, where feasible to encourage the exploitation of those resources. For China, this relationship was launched under the administration of V.K. Ting (pinyin: Ding Wen-jiang), Director of the Geological Survey of China from 1913 to 1921. Born in 1887, Ting's family sent the teenager to Japan for schooling. In 1904, he traveled to Britain and studied mineralogy and geology at the University of Glasgow. Returning to China in 1911 shortly before the May revolution that ended the Qing Dynasty, Ting understood the need to accelerate the infusion of western science into China. It was recognized that Japan had already bridged this divide and that China was far behind. Aware that traditional Chinese scholars led a sedentary life that looked down on any sort physical labor required for fieldwork, Ting believed that a new start must be made with western scholars equal to the task of training Chinese geologists.

Ting went to the United States and personally recruited a professor from Columbia University, Amadeus William Grabau, to fill a joint appointment as Professor of Paleontology at Peking University and Chief Paleontologist at the Geological Survey of China. Grabau's tenure began in 1920 and continued until the end of his life in 1946. Ting eventually rose to the office of Secretary General of the Academia Sinica (equivalent to the US Academy of Sciences), where his influence grew in the support of science in China. It was Grabau who trained the first generation of academic paleontologists in China, who went on to impact the field in their homeland both with regard to industry and culture.

Professionalization of Geology and Paleontology in China

One of Grabau's most able students was Wang Yu, who in 1944 was sent to the Smithsonian Institution in Washington, D.C. to study fossil brachiopods, which world-wide represent one of the most prevalent groups of marine fossils especially in Paleozoic rocks between 540 to 250 million years in age. When he returned to China in 1946, Wang brought with him an extensive reference collection of brachiopods consisting of 50 drawers of specimens that came to be housed at the Nanjing Institute of Geology and Palaeontology, a branch of the Academia Sinica chartered in 1950. His assigned project at the Smithsonian re-examined brachiopods from the Upper Ordovician of eastern Iowa, which supplanted the work initiated by David Dale Own in 1839 and later paleontologists. Wang's research in the United States was published in a prestigious American journal a few years after his return to China.[7] Living and working in Washington, D.C. during the mid-1940s, Wang was certainly familiar with the Smithsonian's central building, for which David Dale Owen served as a consultant choosing its distinctive red building stone.

As a geology student at the University of Iowa, I knew nothing about Wang Yu's work on those Iowa fossils, but learned about his mentor, the professor from Columbia University who left for China in 1920 to teach at Peking University. Beginning in 1973, my own studies as a graduate student at the University of Chicago grew to focus on strata rich in brachiopods from the Silurian of eastern Iowa and I scoured the library for everything I could find related to those rocks and fossils of comparable age elsewhere around the world. In the basement of Regenstein Library, I discovered the crowning piece of work from Grabau's academic career published in Peking in 1940 with a limited print-run of 800 copies: *The Rhythm of the Ages*.[8] Grabau's masterpiece features a stunning set of 23 colored paleogeographic maps depicting the changing relationships of continents from Cambrian time (more than 530 million years ago) to the near present, half of which were bound into the volume as fold-outs. Mesmerized by the prescient vision of this international scholar who published some 35 years before the onset of the plate-tectonics revolution, I sat glued to the floor in the subterranean and dimly-lighted library stacks, where I opened the folded maps one by one and marveled at their contents. Maps showing global reconstructions for the oldest time periods were drafted from the perspective of the Earth's south pole, inscribed by concentric lines of latitude that radiated out beyond the paleoequator to more northern latitudes.

What caught my attention from the book's preface was Grabau's insistence that over geologic time, planet Earth remained bipolar with distinct Artic and Antarctic regions subject to glaciation. Moreover, he maintained that patterns of atmospheric circulation and variable rainfall remained static in tropical and temperate zones aligned with the Earth's equator. What changed through time, however, was the position of the Earth's continents with respect to latitude. The map for Silurian Pangaea (Fig. 1.3) was of particular interest due to my intention to explore regional relationships in climate during that time period roughly 425 million years ago. Grabau was an unusually experienced geologist with a background in the geology of North America, Europe, and increasingly China, but he had never traveled to Africa. Even so, his map for Silurian Pangaea shows a polar ice cap, half on land in North Africa and half offshore as sea ice. Elsewhere in the geology stacks of Regenstein Library was the massive volume published in French from 1971 regarding the Lower Paleozoic of North Africa with photographic details of a former glaciation based on deep gouges cut in Ordovician strata by the movement of overlying ice.[9] Grabau's intuition about a late Ordovician to early Silurian ice age proved to be correct.