GEOLOGY & SOME OF THE MINERAL RESOURCES OF CHINA

THE GEOLOGY

and

SOME OF THE MINERAL RESOURCES OF CHINA

By

Wu Chow Chu
周 武 朱

McGill University

Montreal, Canada

April 12, 1916.

CONTENTS.

CHAPTER I.

INTRODUCTION

The science of geology evolved from the study of cosmogony, while cosmogony, which in the very early days was studied as a matter of speculation in the light of philosophy, originated in mythology. According to the mythology of the ancient Egyptians, it was Muduk who, assisted by his gods and the winds, created the heavens and the earth out of the body of Tiamat whom he had vanquished. The old Greeks believed the Olympian gods were the makers of the universe; whereas the Hebrews maintained that it was the Personal God who created the universe. The ancient Hindoos developed two systems of thought concerning the formation of the universe. According to one system - "All things were originally brought into existence by the sole will of a single First Cause, which existed from eternity."* According to the other system, "There have always existed two principles, the one material but without form, the other spiritual and capable of compelling inert matter to develop its sensible properties."*1
The conception of the formation of the universe held by the ancient Chinese was somewhat similar to that of the "First Cause" and the "Two Principles" of the Hindoos, but differed

---

* Principles of Geology, Vol. 1, p.6, C. Lyell.

*1 Ibid P. 6-7.

in the fact that in the Chinese account there was no spiritual force involved and that the "cause" and "principle" were not separate, but in evolution and union. According to this conception, the first cause was Tai-kieh* or extra-eternity, and the two principles were "yin" and "Yang", or the Negative Principle and Positive Principle. The order of evolution was believed to take place in this manner: Tai-kieh begot two principles, Yin and Yang. The Yin and Yang by their unison begot four "seang", the major Yin, the minor Yin, the major Yang and the minor Yang. By the transmutations of the four "seang", all things were formed. A cycle of the universe consists of twelve "hwuy", and each "hwuy" lasts 18,000 years. When the cycle is completed, destruction comes, and a new beginning follows. The genesis and destruction repeat in this manner for ever. From this it is seen that the conception of the ancient Chinese was metaphysical rather than mythological and spiritual. A later theory that prevailed was that before the heaven and the earth became separated, there was a mass of gas, the lighter portion of which gradually rose and subsequently formed the heaven, while the heavier portion gradually sank and formed the earth.

In the time of Aristotle, the Chinese knowledge of the universe possessed a certain degree of scientific truth.

---

* Kan-keen Yih-che Luh, Vol. I, page 1.

The notable personage at that time was Chwang-tsze.* He maintained that in addition to our earth there were many other planets. In comparing the size and number of the planets, he figured our globe as possessing the dimensions of a mustard seed. He explained the blue tint of the sky*1 as the true color of a thick volume of atmosphere, which he called the "Wild horse". He wrote as follows:- "Is the blueness of the sky its proper color?, or, is it an effect of remoteness in distance? When viewing from above, one will observe the same phenomenon."

We have no direct record to show when the Chinese began to survey their mountains, plains, lakes and streams, or when they began to utilize their natural resources. We know, however, from facts that were early recorded*2 that Fu-he in 2953 B.C. had migrated, perhaps following the bank of the Huang-ho or Yellow river, from Shen-si, the province in which he was born to the province of Ho-nan where he established the first capital of the land. To him was ascribed the initiation of the art of the domestication of animals, the introduction of fine arts, and of organized government. Shen-nung (reigned 2838 - 2698 B.C.) the father

---

* Chwang-tsze was one of the most profound thinkers of the Chow philosophy. He had written extensively and some of his works were preserved to us. See "Chwang-tsze" (in Chinese) 2 vol.

*1 The sky to many people had been a tangible body possessing aproper color-blue. To correct this misconception, Chwang-tsze gave this elucidation.

*2 Reference: Kang-keen Yih-che Luh.

of agriculture and medecine, travelled far and wide "to sip the fountains and taste the herbs in order to discover means of healing." We may conclude that the first extended examination of their lands by the Chinese with a view to utilizing them was begun by Fu-he and Shen-nung.

We have already seen that the formation of the Middle Kingdom and the rise of her civilization took place along the Yellow river, and now let us see what influence the Geology of China had in determining the character of the many branches of advancement that were made by her early inhabitants. The lower portion of the Huang-ho valley was the cradle of the Chinese nation. The Yellow river rising from the Tibetan plateau and passing through Sze-ch'au thence into Mongolia, and then once more enters China proper in about 111 degrees E. It then flows southward making a natural boundary between Shen-si on the west and Shan-si on the east, and at 32½ degrees N. latitude, it turns eastward forming a dividing line between the provinces of Shan-si on the north and Ho-nan on the south. Its course continues eastward cutting through the province of Shan-tung, reaching the Yellow sea in about 37° 50' N. lat. The total length of this river is about 2400 miles. Finding themselves with scanty means of sustenance in the Mongolian deserts, the Chinese were compelled to migrate southward, probably following the Yellow river. When they reached the province of Ho-nan, their nomadic existence was replaced by an agricultural life. What the Nile was to the ancient Egyptians, the Huang-ho was to the ancient Chinese. The lower portion of this river has been a region of disastrous floods for centuries, and hence the country bordering the river has been a land of fertility. Here it was the great Chinese nation developed and maintained a political and intellectual supremacy for 3000 years.* The best form of government, the most ideal society and the highest intellectual life pervaded this region prior to the Christian era. It is an interesting fact to note how the geology of the Huang-ho had an influence upon the Chinese civilization in other ways than those just mentioned. It is recorded that Tsang-kee by observing the foot-prints of birds and quadrupeds, which undoubtedly had been made upon the mud deposited by the inundations of the Yellow river, was led to the invention of the Chinese writing. The system of the Chinese writing was hieroglyphic, and even in the modern form, in many cases, the characters can be traced back to the pictures of the objects which they were intended to represent. Take for example the word kin or gold. Under the modern form, it is written 金 , while the older form was written  and the original form was, with great probability because of logical reason, written  or some form near to it. This last form resembles a gold nugget which was, there is good reason to believe, found along the banks of the Huang-ho. Furthermore, the Chinese compass was invented in about the same time. The magnet used was probably a piece of native iron that possessed the

---

* After the fall of the Chow dynasty (ended in 255 B.C.), the political and intellectual supremacy of China began to shift southward.

property of magnetism. The third metal used was copper, it being first mined in the Show mountain by Huang-ti for the cast of three sacrificial vessels. The arts of casting, moulding, cutting and polishing have been practised by the Chinese since the dawn of history. The Chinese vocabulary is so rich in words pertaining to metals, stones and gems, and their classics were flooded with terms borrowed from the arts which have been mentioned.

Since the Chow Dynasty, laws concerning the control of the mineral wealth have occasionally been enforced, and mines have often been operated on a small scale by the government. Nevertheless the vast mineral resources of that country have hitherto been developed only to a comparatively small extent. Before the Republic came into existence in 1912, the Mining law of China was very unfavorable to mining enterprise, and thus in the entire country there were only a few mining companies, each of which had a capital of ten million dollars. To encourage the mining industry, a revision of the old Mining Law was made in 1913.

It was very early in history that China began a survey of her lands. When the land was deluged, Yu the Great was ordered by Emperor Shun who reigned from 2255 to 2205 B.C., to dispel the waters. He had surveyed the regions of the Huang-ho valley and the Yang-tsze-kiang valley. Practically, all of the dynasties made charts of the empire. Notwithstanding, in so far as the writer could find evidence, China has not undertaken any geological survey in the modern sense of the term. Within late years, the Chinese Government has employed some foreign geologists but their investigations were confined to a few known mining districts, and nothing has been done in other areas. The great problems connected with the Geology of China were not seriously attacked until F. V. Richtofen set his feet on the soil of that country, and the years during which the work progressed are now given:-

1. By F. V. Richtofen:

1st	survey	(1868)	- Che-kiang and Kiang-su.
2nd	"	(1868-1869)	- Lower Yang-tsze.
3rd	"	(1869)	- Shan-tung
4th	"	(1869)	- Kiang-si and Che-kiang.
5th	"	(1869-1870)	- Kwang-tung, Hu-nan, Hu-pei, Ho-nan, Shan-si and Chih-li.
6th	"	(1870-1871)	Che-kiang and Ngan-hwei.
7th	"	(1871-1872)	Mongolia, Shan-si, Shen-si, Sze-Chuan and Hu-pei.

II. By Graf Szcheny and V. Lo'czy:

(1877-1884 ?) Kiang-su, Kiang-si, Hu-pei, Yellow river region, Kan-suh, Sze-Chuan, Tibet and East Turkestan.

III. By Obrucheff: (1884-1886) Northern Chih-li, Shan-si, Manchuria and Mongolia.

IV. By a party of ten sent by a Chamber of Commerce of France:

(1887) Kwang-si, Ho-nan, Yun-nan, and Sze-Chuan.

V. By Japanese geologists: Within late years the Japanese geologists have made extensive surveys in the eastern section of China.

VI. By a party sent by the Carnegie Institution of Washington, D.C., of the United States:
(1903-1904 Northern and Central China.

It is obvious that China needs a Geological Survey. Her millions must be better taken care of and this can only be done through the development of her natural resources. Her people should be taught to appreciate the important part that geology and the other natural sciences should play in a rational development of her resources.

Geography.

The Chinese Republic is composed of China proper,* Manchuria, Mongolia*1, East Turkestan, and Tibet. It has an area of about four million square miles and a population of four hundred millions. It occupies South-eastern Asia and is bounded by the Pacific Ocean on the East, Asiatic Russia on the North, Turkestan on the West, and by India and Burma, together with French Indo-China on the South; it lies between latitudes 18° 50' N. to 55° 25' N., and longitudes 75 degrees E. to 135 degrees E. From north to south, throughout the greater part of its area, China is more than 1800 miles in length. The greatest of all distances extending in a straight line in any direction is that from the north-eastern corner of Manchuria to the south-western confines of Tibet. This is 3100 miles in a direct line. Following the indentations of the coast from the Gulf of Liao-tung in the north to the Gulf of Tong-king in the south, the sea-board of China is about 5000 miles in length. The two peninsulas (the peninsula of Shan-tung and the peninsula of Liao-tung) are situated in the north. On the whole the Chinese coast is comparatively smooth, forming a semi-circle with its most easterly point in 30 degrees N. latitude, which is also midway between its southern and northern extremities. From this point where Hang-chow Bay is situated to the Gulf of Pe-Chi-li the shores

* China proper consists of the following provinces: An-hwei, Che-kiang, Chih-li, Fu-kien, Ho-nan, Hu-nan, Hu-peh, Kan-suh, Kiang-si, Kiang-su, Kwang-si, Kwang-tung, Kwei-chow, Shan-si, Shan-tung, Shen-si, Sze-ch'uan, Yun-nan.

*1 In 1913, Outer Mongolia was given Autonomy by China.

are flat and alluvial, while south of this point to the Gulf of Tong-king, the shores are precipitous and rocky. In the northern portion, there are two gigantic rivers, the Huang-ho and the Yang-tsze-kiang, while in the south there is only one, namely the Si-kiang which is much smaller than either of the other two. For this reason, the best natural harbours, namely, Fu-chow, Amoy, Swatow, Hong-kong and Kwang-chow-wan are lying to the south of this naturally dividing point.
If not approached from the sea, China is not easily reached, since it is separated from the rest of Continental Asia by lofty plateaus ranging in height from 3,000 to 18,000 feet and rugged mountains whose passes vary from 10,000 to 16,000 feet above sea-level. Thus China, occupying the most favorable portion of Asia, developed and maintained an independent civilization for more than four thousand years.

CHAPTER II.

PHYSIOGRAPHY.

The most striking feature of the physiography of Eurasia is the rhythmetrical character of the trend lines of its mountain ranges. Excluding the Ural range and the Kiolen Mountains, all the mountains of this great Continent press toward the coast that bounds the Pacific Ocean, the Indian Ocean, and the Mediterranean Sea. The ranges in this assemblage are frequently harmonious in their orientation, but some of them interfere with one another. In general, however, they form a grand curve resembling the catenary type, having its two extremities hooked respectively at Behring Strait in northeastern Asia and from the Alpine region in southwestern Europe, and with its center of gravity at the protuberance of southern Asia. The general aspect of this assembled chain presents a series of rippling trends. All the individual ranges are more or less arcuate in form. In general, those constituting the southwestern portion of the chain are concave towards the northeast; those of the middle portion are convex toward the south; and those forming the eastern and northeastern portions are concave toward the northwest. But it is to be noted that sometimes one range shows a series of concave curves.

Viewed from another standpoint, the ranges of this great assemblage radiate out from a common knot in Pamir.

Five principal branches are generally recognized: (1) The Tien-shan branch, which stretches in a northeasterly direction; (2) the Kuen-lun branch which lies south of the Tien-shan branch and advances towards the east; (3) the Himalayan branch which trends southeasterly and south of the Kuen-lun branch; (4) the Sudiman branch, which takes a southwesterly course, and (5) the Hindu-kush branch which shoots westward. This common knot, the Pamir, is sometimes referred to as the 'roof of the world'. The maximum altitude of its peaks reaches 25,000 feet above the sea. From the elevated region of Central Asia, a number of large rivers issue. On the east, starting in a counterclockwise order, are the Si-kiang, the Yang-tsze-kiang, the Huang-ho, all of which flow through China, together with the Amur which in part forms the boundary between Siberia and Manchuria. All of these rivers empty into the Pacific Ocean. On the north, the Lena, the Yenisei, and the Ob, flow into the Artic Ocean. On the west, are the Obi, which enters Lake Balkhash, while the Sir and the Amu drain into the Aral Sea. On the South, the Indus, the Ganges, the Brahmaputra, the Irawadi, the Salwin, the Mi-kong, and the Song-ka, debouch into the Indian Ocean. It must not be conceived that the elevated area from which the principal mountain and river systems spring is a dome possessing symmetrical slopes. In fact, the slopes descending on the east, north, and west of this elevated area are gentle, whereas that on the south is abrupt.

From the foregoing, it is seen that the surface of

Asia is extremely mountainous in the south, and is traversed by numerous rivers. The present configuration has been brought about by combined processes of sinking, rising, compression and weathering. Geologists have advanced various theories as to the interpretations of these processes. The results of weathering are evident and therefore need no discussion. Regarding the other processes, Suess and Bailey Willis have offered some very comprehensive explanations. According to Bailey Willis' idea, Asia consists of two types of continental elements, which he called the positive and the negative elements. Throughout geological time, the positive elements have shown a decided tendency to rise, while in contrast, the negative elements have in general been characterized by subsidence. A positive element is recognized by great unconformities or the complete absence of great thicknesses of sedimentary rocks, whereas a negative element is recognized by the prolonged accumulation of sediments. Throughout geological history, the narrow strip of the continent which borders the Japan sea, China and part of the Indian ocean, in other words, the strip extending from East Cape to Tong-king Gulf, forms one positive element, the 'Eastern Element'. The region north of the Irkutsk amphitheatre in Siberia forms the 'Siberian' positive element. The Tarim Basin and Gobi Desert form the 'Mongolian' positive element. The Gondwana Element forms the peninsula of South India. Part of the rest of Asia consists of negative elements. It is to be noted that the positive elements are wholly confined to eastern Asia. These continental elements, positive or negative are supposed to be conditioned by differences in the density of their masses and this is held to be the cause of the phenomenon known as "vertical movement."

As the "vertical elements" simply effected the rising and sinking of the lands and had little or no direct influence in the orogeny or mountain building, the present mountain systems of Eurasia are not the results of these movements, but were formerly the compressive forces that have been active at intervals since the pre-Cambrian time. To explain the underlying factors in the production of the Eurasiatic mountains, Suess maintained that in Pre-Cambrian times, there existed an area in the region of Angara (long.90 degrees - 120 degrees E. and lat. 50 degrees - 70 degrees), which in course of time was compressed to a rigid mass. When this nucleus was again acted upon by a tangential force, a series of arcuate mountains developed which in general are parallel to its southern border. At long intervals of time, this first series of mountains was in turn subjected to crustal compression, and further mountain ranges were uplifted in succession further and further away from the core; thus the mountains were formed with a rhythmetrical orientation which constitutes the catenary curve above described. According to this theory, the crustal forces were exerted from the north towards the south. Suess' theory seems in accord with the configuration as it appears today, but his theory does not explain how the crustal forces originated. Bailey Willis has assumed that the forces originated in the

Indian and Pacific oceans, and he has maintained that the forces acted northward and northwestward.

As the pressures exerted upon the suboceanic masses are relatively greater than those upon the subcontinental rocks at the same level, the suboceanic masses are forced to move in the zone of flowage probably about 50 miles below the sea floor toward the continent, in consequence of which the continental masses are bulged up at the weak points of resistance and mountains may be formed. Since Suess' nucleus in the Siberian land was rendered rigid prior to the Cambrian age, the deeply suboceanic material beneath the Pacific and the Indian oceans was thus able to exert a force toward the north which might act upon that ancient rigid nucleus. By reason of the presence of the latter, reactional forces may have been generated, which radiated out towards the south, and as a result, a series of cresentic mountain ranges may have formed. In general, the outermost series of mountains was developed last and is believed to have been formed during the Tertiary. The Himalayan range was formed in this period.

In the following pages our attention will be confined to the lands of the Chinese Republic. Starting from the Asiatic plateau, we first perceive an oval shaped tract of land elevated to a mean height of about 15,000 feet above the sea. This is the land of Tibet, and one of the continental positive elements. On the east, it is bounded by the Yung-ling ranges which trend north - south, and the Sze-ch'uan depression which has been maintained at a low level since the Cambrian or pre-Cambrian times. The northern limit of the Tibetian positive element is the Kuen-lun system which was covered by a sea during the Paliozoic age, while its southern and western boundaries are the Himalayan range which remained under water till the Tertiary. Thus Tibet is surrounded by zones of the negative element. The surface of Tibet is mountainous and rugged. Its highlands have an average altitude of over 16,500 feet; its valleys range from 12,000 feet to 16,000 feet; its peaks vary from 20,000 feet to 24,000 feet. There are sedimentary rocks in Tibet of Jurassic and Createaceous ages.

Chinese Turkestan occupies an elliptical area, bounded by the Kuen-lun range on the south and the Tien-shan range on the north. It covers the basin of Tarim which is a part of the Gobi Desert and has been a positive element (part of the Mongolian Element). The country is less elevated than Tibet. Its geologic history is not known, except that quartzites and slates have been observed, which may be of Proterozoic or early Paleozoic age.

Mongolia, with Sungaria on the west, lies north of Chinese Turkestan and China proper, west of Manchuria, and south of Siberia. This region is characterized by an immense amount of shifting sands, and by scarcity of water bodies and vegetation. The elevation of this region ranges in general from 2000 feet to 4000 feet but in some places actually descends to below sea-level. On the whole, it is a basin-shaped depression with no outlet to the sea. Because of these facts, the Mongolian Desert is often called by the Chinese as Sha-mo (boundless sand) or Han-hai (dry-sea) or Puh-Mo-ti (hairless land). It is believed that Mongolia was once occupied by an inland sea which became extinct in the late Tertiary and Quaternary waste. The desert region is girdled by mountain chains and highland. On the east are the Khusgta and the Great Khingan; on the north are the Yablonoi, the Baikal, the Sayanskii, and the Altai; on the west is the Pamir highland, and on the south is the Kuen-lun range. A portion of this district has been considered as a positive element.

Manchuria lies east of Mongolia, north of Korea and the Gulf of Pe-chih-li, south of Amur and west of Japan sea. The natural boundary on the north is the river Amur and that on the west is the Great Khingan range which extends from the Amur to the Chinese frontier near Peking. The country is comparatively low and possesses no striking features. Its geology has many points in common with that of northeastern China.

Orographically China Proper is but the continuation of the Tibetan and the Mongolian plateaus that slope into the Pacific Ocean. Topographically, however, the country has a very wide range of altitudes. The fact is that the western provinces, Yun-nan, Sze-Ch'uan, and Kan-suh, through which many branches of the great ranges, the Kuen-lun, and others under various names, such as the Altin Tagh and the Nan-shan, make their entrance into China, attain elevations ranging from 10,000 feet to 16,000 feet above sea-level. Some of the peaks even exceed 20,000 feet in height. The delta plains, on the other hand, range from 1000 feet to sea-level. The southern division is much more elevated than the northern portion. The average elevation of the entire country has been estimated to be 1500 feet above the sea.

On the whole, the surface of China is rather hilly and mountainous, and when considered locally, its configuration is very diversified. For more detailed description, the country may be divided mainly on the basis of physical features, into Northern, Central, and South China.

Northern China includes the drainage basin of the Huang-ho and the margin of the Mongolian plateau that descends so steeply to the Great Plain. It is separated from Central China essentially by the offshoots of the Kuen-lun Mountains, such as the Pe-ling and the Tsin-ling mountains, the Fu-niu-shan. The heights of these mountains decrease toward the east. The maximum of the Tsin-ling, for instance, is 13,000 feet, while the altitude of the Fu-niu-shan, which is the continuation of the Tsin-ling, decrease imperceptibly until it merges with the Great Plain. The western section of this division, mainly occupied by the provinces of Kan-suh on the west and Shen-si on the east, contains many offshoots of the great range of Central China in the form of minor anticlines. In this region, which is chiefly underlain by limestones, sandstones, and cool seams, trough-like depressions are often observed and deep gorges are numerous. Northeast of Shen-si, lies the elevated plateau of Shan-si, which is rich in coal. This area is a part of the Mongolian plateau, but its eastern edge where it overlooks the Great Plain, represents a great fault with a vertical displacement of, probably, 2,000 feet.

The Central division embraces the Yang-tsze basin, the province of Sze-Ch'uan, and part of Yun-nan. Its southern boundary is not well defined. Many of the tributaries of the Yang-tsze-kiang come from the south. The river itself takes its rise in Tibet (as also does the Huang-ho), and passes through Yun-nan and Sze-Ch'uan. As has been noted before, Western China is but the continuation of the Tibetan highland. The western half of the Central Division is occupied by a red sandstone known as the Red Basin of Sze-Ch'uan. It is separated from the Yang-tsze basin by mountains of great height. This vast province is important physically to the Yang-tsze-kiang because it has no considerable water-retaining bodies. It sends practically all its run-off into the Yang-tsze-kiang. Owing to the accession of great quantities of water the upper portion of the Yang-tsze has been cut into grand canyons and wonderful gorges. The most important affluent of the Yang-tsze-kiang is the Han-kiang. The Yan-tsze with a total length of 2,900 miles, although navigable by large steamers only for 1,000 miles from its mouth, is important to the geology of China as well as to her commerce. Its course is very irregular; after leaving Sze-Ch'uan, it visits every province of Central China, and by its frequent undulations, extensive flood plains have been built up about its lower course.

As previously stated, there is no sharp line by which the central and southern divisions may be established. The southern division, however, is assumed to include Yun-nan, Kwei-chow, Hu-nan, Kwang-si, Kwang-tung, Kiang-si, and Fu-kiang. The surface of this division, except for a few small deltas and mature valleys, is uniformly mountainous. Excluding these in Yun-nan, its mountains, however, are comparatively low. Si-kiang is the only river of considerable size. It rises in Yun-nan, traverses Kwang-si and Kwang-tung and empties itself in the China Sea. Its length is about 1000 miles.

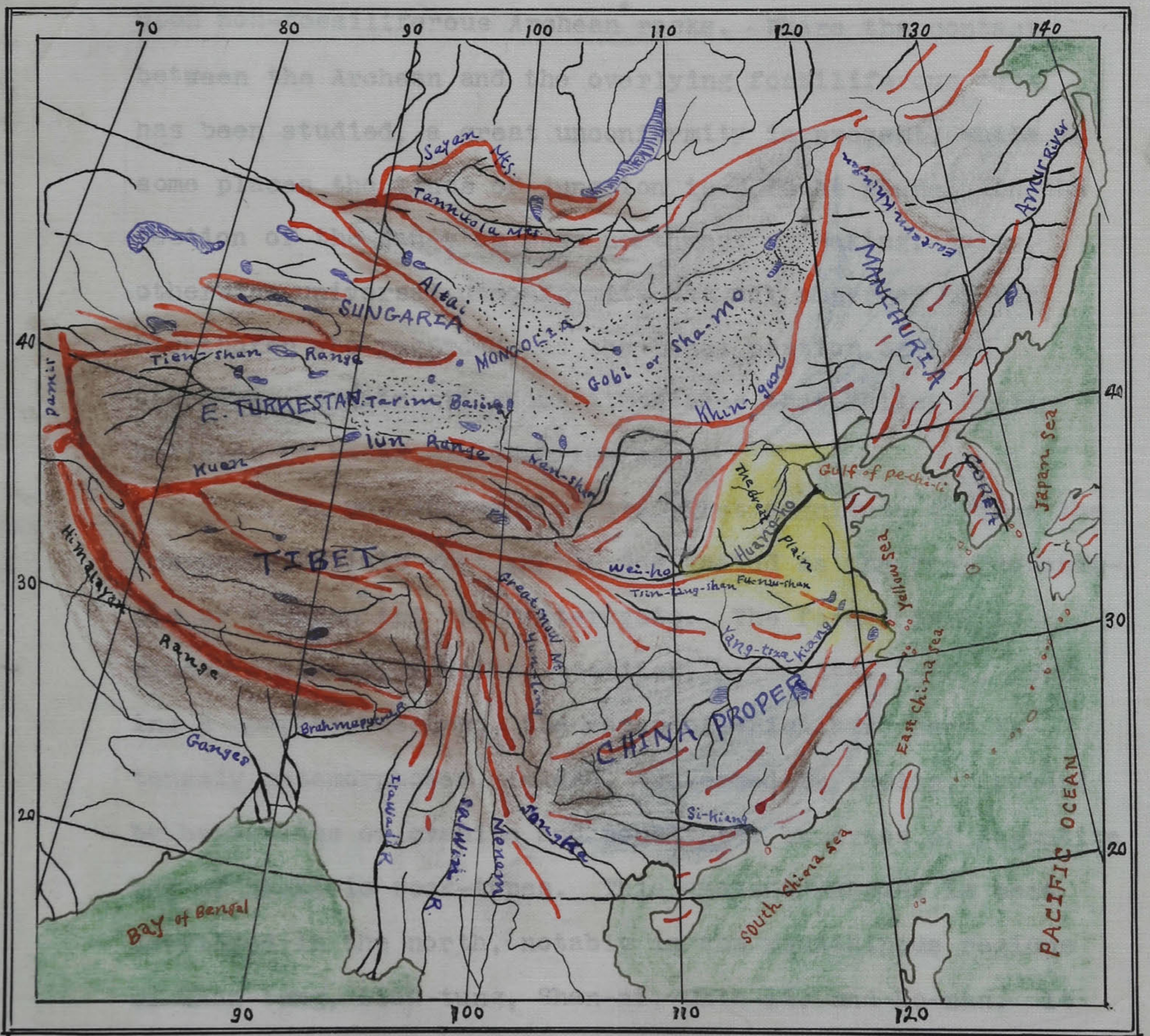
In the following, a few general statements pertaining to the geological history of these lands and especially to China Proper, are briefly enumerated. Sometime, prior to the Cambrian period, the land of China, northern China at least, underwent a severe diastrophism in consequence of which the rocks were highly metamorphosed and mountain ranges formed. This episode has been revealed by the study of the ancient rocks from the province of Shan-si, Chih-li, and Shan-tung. Following this ancient diastrophism, the mountains were eroded to a very low relief, probably leaving a few hills here and there. Excepting the southeastern margin which has been maintained above water since the pre-Cambrian times to the present days, this eroded land was eventually overrun by the Paleozoic Sea, probably leaving the higher hills above water in the forms of islands. Thus enormous sediments were accumulated on the sea-floor forming the so-called Sinian formation (Cambro-Ordovician). At the end of the Sinian period, the submerged areas were uplifted. By the beginning of the Silurian period, the land was again submerged and remained under water through the Silurian, Devonian, and the Lower Carboniferous periods. By the latter part of the Carboniferous, the Paleozoic sea again receded, perhaps leaving behind some of its arms; thus from this time to the Jurassic, China was covered by sea-arms, marshes, and dry lands. China has been a land surface since the Jurassic to present time.

During the Permo-Mesozoic, the raised districts suffered deformation, and anticlinoria and synclinoria were formed. The ranges of the Tien-shan, Kuen-lun, Tsin-ling, and Wu-t'ai were produced in this period. Moreover, the folding event was accompanied by intense intrusions. Through the course of time, the anticlinoria were eroded to rugged ridges, whereas the synclinoria were carried into deep valleys. The Huang-ho and the Yang-tsze-kiang probably began their life history in this period.

From the mid-Mesozoic to the Tertiary, China was in a state of quiescence, but, geologically speaking, it was a stage of great erosion, and hence no cretaceous rocks are found in the country. In the middle and late Quaternary (probably), North China suffered intense warping--the faults exhibited in the ranges of Ki-chou-shan, Ho-shan, Hua-shan, and Tsin-ling in Shan-si and Shen-si were formed by movement during this period. Another notable event, pertaining to the geology of China, is the formation of the yellow earth or loess. The processes whereby this formation developed have been active since the Pliocene and are still in progress today.

EASTERN ASIA.

MOUNTAIN and RIVER SYSTEMS.



Trend lines. Rivers and streams.

Lands 6000-12000 ft. Lands 3000-6000 ft. Lands 600-3000 ft. Lands 0-600 ft.

CHAPTER III.

GENERAL GEOLOGY.

As elsewhere in the world where the basal strata of the Cambrian are exposed, in China, they are found to rest upon non-fossiliferous Archean* rocks. Where the contact between the Archean and the overlying fossiliferous rock has been studied, a great unconformity is present, while in some places the lines of junction is a fault plane. In the section of the Nan-k'ou pass northwest of Peking, this otherwise universal unconformity was not observed by Von Richthofen who regarded, as the basal portion of the Cambrian, certain siliceous limestones that Bailey Willis believes to be of Pre-Cambrian age.

An unconformity of the first magnitude divides the Pre-Cambrian into what may be designated as the Pre-Proterozoic or Archean*1 and the Proterozoic. The former term includes gneisses, schists, granites, pegmatites, etc., forming a complex basement, the rocks of which have been intensely metamorphosed, folded, traversed by faults, invaded by batholiths of granite and penetrated by dykes of pegmatite and of basaltic rock-types. This ancient complex is best developed in the north, notably in the mountainous regions of Shan-tung, Liao-tung, Shan-si, Chih-li, and Ho-nan. It

---

* The term Archean is here used as an equivalent to Pre-Cambrian.

*1 Today the term Archean is more generally applied to Pre-Proterozoic rocks.

is also found in the Kuen-lun range and in the Tsing-ling-shan. In the south its occurrence is very limited. The granite-gneiss in the vicinity of the Huang-ling-miau on the middle Yang-tsze is the only notable exposure.

The Proterozoic rests unconformably upon this basal complex, as is illustrated by the exposures in the Wu-t'ai region and in Shan-si. In other localities, as in Sze-Ch'uan and the lower Yang-tsze gorges, the Sinian (Cambro-Ordovician) strata are found overlying masses of gneiss, gneissoid quartz-diorite, diorite, and granite. If this group of rocks is regarded as belonging to the Pre-Proterozoic, the Paleozoic strata then lie immediately upon the Archean complex; if, on the other hand, it is considered as Proterozoic, then the stratigraphical relation between the Pre-Cambrian and the Cambrian is the same in these districts as in Shan-si; but Blackwelder who studied these rocks in the field was unable to definitely determine their age. In western Shan-tung, Sinian formations have been observed resting unconformably upon the T'ai-shan complex (the basal complex). Thus, in some places, the Cambrian rocks are in direct unconformable contact with Proterozoic and in other places with Pre-Proterozoic rocks. The rocks of Proterozoic age are, for the most part, of sedimentary origin, including mica and chloritic-schists, magnetite quartzite, felspathic quartzite, siliceous marble quartzite, conglomerate, jasper, slates and limestones.

The Sinian (Cambro-Ordovician)

The application of the term Sinian varies with different writers. By Pumpelly, who was the first to employ the term, it is applied to "the prevailing structural axes of eastern Asia, which trend east and southwest"; by von Richthofen, "to designate a series of conformable strata which exhibit folds having the Sinian direction:; while, by Bailey Willis, to designate strata of Cambrian and Ordovician ages.

In China, an unconformity is usually present at the base of the reddish Sinian formations. This important relationship was observed both by Richthofen and by Bailey Willis. In some localities, as in the Nan-k'ou pass, northwest of Peking, it seems probable that this unconformity may not exist. The distinctive Cambrian formation which in other localities rest unconformably upon the Proterozoic rocks, may there be observed to conformably overlie certain non-fossiliferous limestones that Richthofen included within his Lower Sinian. But after the more intensive studies of Bailey Willis had been completed, Richthofen expressed agreement with the decision that these limestones are probably of Proterozoic age and equivalent to the Hu-t'o system.

In accordance with the definition of Sinian by Bailey Willis, there are three series included in that System

--the Lower, the Middle, and the Upper Sinian. The Lower Sinian is widely distributed throughout northern China. It includes shales, sandstones, limestones, and occasionally some conglomerates, which are celebrated for their varied colors. Different strata display variable shades of red, brown, yellow, and gray. A typical section showing the characteristics of the Lower Sinian is found in the Man-t'o-shan of Shan-tung, where in ascending section a series of soft yellow shales, buff earthy limestone, gray and buff calcareous shales, maroon shale, oolitic shales and oolitic limestone have been observed lying upon a red granite. Of the twenty-one formations in the succession exhibited in that district eleven are of shale, which constitutes two-thirds of the total thickness. These shales are intensely red in color, and since they are pre-eminently developed in the Man-t'o mountain, the Lower Sinian series is often known as the Man-t'o shale.

From the preceding, it is seen that the predominant rock among the Man-t'o group is the red shale. In contrast, the shales of the Middle Sinian are of a green color. In addition to the green shales, bluish, black, and gray limestone are also present, the gray varieties frequently possessing an oolitic structure. These rocks are most typically developed in the Kiu-lung range of Shan-tung. There the green shales and the limestones possess a thickness of 900 to 1000 feet and rest directly upon the Man-t'o formation.

Special interest is attached to the Kiu-lung formation, because it contains a great wealth of Middle Sinian fossils. Remains of trilobites and brachiopods are exceptionally abundant in the Kiu-lung limestones and shales.

In the vicinity of the Tsi-nan in Shan-tung, limestones and shales of the Upper Sinian are typically developed. The lower portion of the Upper Sinian, 75 meters thick, consists of shales and coarsely, crystalline dolomite, while the upper portion, 750 meters or more in thickness, is composed of dolomitic limestones. In contrast to the Middle Sinian, which is of Cambrian age, the Upper Sinian is less distinctly stratified, its rocks are dark to brown in color, and the few fossils that have been collected show it to be of Devonian age.

It is only in the province of Shan-tung that the three divisions (Upper, Middle and Lower) of the Sinian are present. For instance, the Man-t'o shales and some limestones which resemble those of the Kiu-lung group, are known to occur in northwest Chih-li and Shan-si, but here no rock similar to those of the Upper Sinian of Shan-tung are present. In Ho-nan, von Richthofen found oolitic limestones in the Lung-monn (Dragon-door) but in that district he did not observe either the Man-t'o shale or the Tsi-nan limestone. Greater dissimilarities are encountered in middle-western China. On the middle Yang-tsze (in the Hu-peh and eastern Sze-Ch'uan), Bailey Willis recorded the presence of limestones which has been designated Ki-sin-ling limestones, 1350 to 1500 meters in thickness, in which both Cambrian and Ordovician fossils are to be found. At the base of this formation, at Nan-t'ou on the yang-tsze lies a stratum, 2 feet in thickness of greenish shale with embedded conglomerate, the pebbles of which have been derived from the tillite or consolidated glacial deposits. This is succeeded by thinly bedded, shaly, oolitic and in part chert-bearing limestones having a thickness of 350 feet.

The presence of this tillite within the Lower Cambrian is one of the most interesting of the geological records displayed by the early Paleozoic rocks in China. Towards the base of the Lower Sinian, as exposed in the gentle slope beneath the cliffs at Nan-t'ou, this tillite or consolidated boulder-clay betrays glaciation during the Lower Cambrian. It is one of the very few localities known in the world where one may study the existence of glaciers in early Paleozoic time. Blackwelder describes the character and relationship of the tillite as follows:

"The next outcrops above the sandstone occur 100 feet (30 meters), up the slope, and expose about 120 feet, (35 meters), of hard massive boulder-clay or tillite, which is neither fissile nor stratified. It is a greenish gritty clay-rock of hackly fracture, in which lie irregular stones of various sizes and kinds, with their long axes at random angles with the horizontal. The rocks represented are gray granite, brow-rhyolite-porphyry, mica-schist, massive green slate, earthy gray limestones, quartz, and chert. The stones range in size from sand-grains to blocks 50 to 75 centimeters in length, and there is no suggestion of assortment of individual sizes. Coarse and fine particles lie indiscriminately mingled and chaotic in their arrangement. The forms of the majority of the stones are sub-angular, i.e., angles are present but are smooth and rounded. The flattish surfaces of such slowly weathering rocks as the massive siliceous ferruginous limestone are polished and scratched in various directions, and are identical in aspect with pebbles from the Pleistocene boulder clays of North America and Europe. The scratched stones were found in numbers firmly fixed in the green tillite, in such a condition as to show that they had never been disturbed nor subjected to surface abrasion since they were there in early Paleozoic time."

Conclusion.

The Sinian formations are extremely developed in the Middle Yang-tze, in the mountain passes between Ho-nan and Sze-Chuan, and in the region about the lower Huang-ho, but they are not definitely known to occur elsewhere. They were formed during the Cambrian and lower Ordovician periods. They are composed of different varieties of limestones and shales with a few beds of conglomerate. They vary in thickness from a few meters to 1500 meters. Finally, their lithological character and their stratigraphical position vary in different regions; but, on the whole, they are fossil-bearing.

Siluro-Devonian.

Under this heading is included those strata which are believed to have been formed within the epoch extending from the close of the Sinian (Lower Ordovician) through the Silurian and Devonian to the Carboniferous. Formations of this age include schists, limestones, sandstones and grits, locally cut by intrusions of granite. These formations are typically developed in the mountainous regions of central China, eastern Sze-ch'uan, southern Shan-si, and western Hu-peh.

From the region between Kiu-kiang and Nan-king, von Richthofen reported a geological sequence of seven different formations, five of which he designated as "the Ta-ho (?)", "the Lu-shan schists", "the Matsu limestone", "the granite intrusions", and "the Tung-ting sandstone". He believed that the Tung-ting sandstone lay conformably beneath the easily distinguishable Devonian limestone (the Si-ho formation). Bailey Willis, however, found that it was impossible to recognize the first four of Richthofen's divisions, while even the fifth is of uncertain position. The sixth in the series is the Si-ho limestone full of chert modules and containing numerous fossils, chiefly corals. (Aulopora repens especially abundant), encrinites, and brachiopods. The seventh in Richthofen's series is known as the Nan-king grits. In this formation are included gritty and very quartzose sandstones, coarse conglomerates composed exclusively of quartz pebbles and certain dark shales which contain indeterminable fossil plants. The sandstones, the conglomerates, and the shales are interstratified.

Overlying the formation just described is Carboniferous limestone which has been called the Ki-tau limestone, and, according to Bailey Willis, consists of three members:

(1) A lower limestone, 420 meters in thickness, characterized by the presence of Fusulina Cylindrica;

(2) Black sandy shales, black lydite, and soft sandstone, about 120 meters thick, containing exceptionally large specimens of Productus semireticulatus, accompanied by numerous other brachiopods, bivalves, corals, and fenestellas; and (3) an upper limestone more than 480 meters thick, which is separated from a bed of coal of the preceding by only a thin stratum of black shale and is similar in nature to the lower limestone." From this it is seen that the Devonian terrane is immediately followed by carboniferous strata, but from the following paragraph, it will be observed that carboniferous rocks often rest directly upon the Ordovician.

Pre-Carboniferous Unconformity.

Bailey Willis notes that: Throughout northeastern China, in the provinces of Chih-li, Shan-si, Shan-tung, and Ho-nan, there is an unconformity which brings the Ordovician in contact with the Carboniferous. Wherever it has been seen the underlying terrane consists of the upper Sinian (lower Ordovician) limestone; whereas the overlying strata are shales which lie a hundred feet or so below beds that carry upper carboniferous fossils, either marine shell or plant remains. The hiatus, appears, therefore, to represent later Ordovician, Silurian, Devonian, and lower Carboniferous times.

This great gap has been proven to exist by local observations. In northern Shan-tung, at Po-shan, that which Richthofen regarded as Kohlenkalkstein (Carboniferous limestone) is in reality Sinian limestone, underlying coal-measures with shale, dolomite, and sandstone. Moreover, Blackwelder has observed a similar relationship in the region between T'ai-yuan-fu and Won-shui-hien, Shan-si, where soft shales with interstratified coal seams lie in close contact with the Sinian limestone.

From these facts, it may be concluded that the Carboniferous in the north lies unconformably upon the Sinian, whereas in Central China it rests conformably on the Devonian.

The Carboniferous.

According to their different modes of origin, the Carboniferous strata of China constitute two distinct series— the marine and the continental. The first is represented by a great limestone formation, having in some places a thickness of 1200 meters, and being characterized by the presence of abundant marine fossils. This marine Carboniferous strata has been identified south of the Tsing-ling-shan, in the provinces of Shan-si, Sze-ch'uan, and Hu-peh; further east along the Yang-tsze-kiang in An-hwei and Kiang-si; in the Kwen-lun-shan and Nan-shan of Tibet, and in the Tien-shan in Eastern Turkestan. Furthermore, it is distributed throughout Southwestern China, Burmah, and the Malay peninsula. It is also extensively represented in the Himalayas.. The second is composed of sandstone and shales, with numerous coal beds and occasional thin bands of bituminous limestones. In the north, it occurs extensively in Liao-tung, Shan-tung, Ho-nan, Shen-si, Kan-suh, and most important of all, in Shan-si. In the south, it is widespread in the provinces of Hu-nan, Kwei-chow, Yun-nan, Sze-ch'uan, Fuh-kien and Kiang-si. In the mountainous regions of Tibet and Mongolia, it is of widespread occurrence. Although this series is termed Continental, undoubtedly, in some localities it includes certain strata that were laid down under marine conditions.

Marine Carboniferous.

In the preceding discussion of the Siluro-Devonian formations, it has been pointed out that the Carboniferous limestone (the Ki-tau), often lies in close contact with the uppermost stratum of the Devonian succession. In the region between I-Chang in Hu-peh, and Wu-shan-hien in Sze-ch'uan 370 miles west of Ki-tau, a similar limestone called the Wu-shan limestone is developed. Here the thickness of exposures range from 1000 to 1200 meters. When broadly regarded, the entire formation is composed of dark gray or blackish limestone with a few seams of shale and local layers of anthracite coal, but certain local variations are worthy of special mention. According to Blackwelder, from the headwaters of the Ta-ning-ho to Wu-shan, the lower part of the formation contains abundant nodules of black flint; at Tung-kuan-k'ou, on the Ta-ning-ho, important seams of coal are of widespread occurrence. The limestone is rich in marine fossils, such as Schwagerin, a Michelinea favositoides Girty, Spirifer Lonsdaleia chinensis Girty, Crinoidal fragments, etc. The Wu-shan limestone is exposed repeatedly in gorges on the upper Yang-tsze in provinces already mentioned.

The Continental Carboniferous

The distribution and general characters of the continental carboniferous formation have already been mentioned. The widespread distribution of these coal-bearing formations, and the frequency with which coal seams occur within them will be of the utmost importance in the future development of China. As typical of the development of this facies of the Carboniferous, a description will be given of the coal measures in Shan-si province.

In T'ien-hua, Shan-si province, a coal field lies in a deeply dissected syncline where the stratigraphic relationship of the strata are distinctly exhibited. At the base, upon the Sinian dolomite, lie pale-yellow, gray, and brown shales which grade upward into variegated sandstones, sandy shales, and clay with frequent bituminous layers. Toward the top, the sequence becomes less shaly; yellowish white and brownish sandstones alternating with thin beds of shale, while coal-seams of varying thickness and purity are interspersed through the lower 100 meters of thickness. The total thickness exposed is 225 meters.

Permo-Mesozoic

In China, as in America, there is no formation by which the Paleozoic and Mesozoic may be sharply separated. It would appear that the Carboniferous was followed by a period of aridity during which the highly colored sedimentary rocks of Permo-Triassic age were deposited.

The Permo-Triassic.

Bailey Willis has proposed the term Permo-Triassic to embrace those rocks formed during the Permian, Triassic, and Lower Jurassic periods. These formations are widely distributed in China, from Shan-tung on the east to Mongolia on the west, and from Shan-si on the north to Indo-China in the south. The type localities occur within Sze-ch'uan province, the upper Yang-tsze valley, and Shan-tung. The Red Basin of Sze-ch'uan shows a very typical development of these rocks. These Permo-Triassic rocks include different varieties of limestones, shales, conglomerates, and occasionally, coal beds. The rocks, on the whole, are highly colored.

In the Red Basin of Sze-Ch'uan, at Kuang-yüán -hien von Richthofen observed two formations--the limestone and the coal-bearing.

(A) The limestone formation:

The thickness of this is 1200 feet, composed of four distinguishable types. At the base lie thin-bedded limestones of yellow, red, and white colors. Above these are thick-bedded mottled limestones, followed in succession by yellow dolomite, and a grayish-white nodular limestone.

(B) The coal-bearing formation:

The limestone formation described above is immediately followed by

(1) Sandy and clayey rocks of yellow and gray coloring; generally thinly bedded and having a thickness of 1000 feet.

(2) Alternating plant-bearing shales and soft sandstones, which are filled with remains of plant stems, having a thickness of 200 feet and including two coal beds, 3 to 4 feet thick. The plant remains have been determined by Professor Schenk as belonging to the lower Jurassic.

(3) Heavy beds of coarse conglomerate, 300 feet thick. The pebbles, which consist of limestone and firm sandstone are coarsest towards the bottom.

(4) Yellow sandstone, alternating with clayey strata. Thickness 1000 feet.

(5) Clayey sandstones, in part reddish. Thickness, 600 feet.

(6) Heavy-bedded greenish sandstone, soft and crumbling, as are all the sandstones of this formation. Thickness, 500 feet.

All the fossils collected by Loczy from this region are almost exclusively remains of plants, some of which have been identified to be of Rhaetic age (transition of Triassic to Jurassic), while others belong to the middle Jura. Formations similar to those in the Sze-ch'uan Basin, just described, have been reported to occur on the Ta-ning-ho and the Yangtze rivers. In these regions, the Permo-Triassic terranes are found lying above the Wu-shan(upper Carboniferous) limestone.

The Jurassic.

In the foregoing paragraph, the occurrence of Jurassic rocks in China has already been noted. The components of the system are chiefly sandstones in association with shale and coal. These rocks are generally red in color and their fossil content is restricted to abundant plant remains. Besides those regions already mentioned, the Jurassaic formations occur extensively in Southern China and to a less degree in Shan-tung, Shan-si, Liao-tung and Shen-si. In Shen-si, in the vicinity of Shan-chou, Loczy observed a basin of Jurassic strata resting upon ancient metamorphic schists. Here, the Jurassic includes fine-grained clayey sandstones alternating with dark, bituminous thin-bedded marls interstratified with thin layers of sandstone.

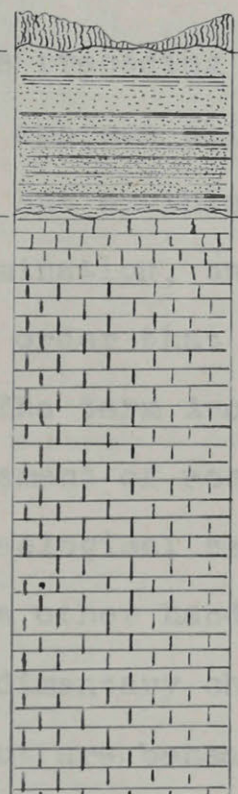
Both in the marls and sandstones numerous carbonized fruits (Carpolithus) are found, which are believed to belong to Cycades or Coniferous fruits resembling taxina.

The Tertiary.

In China, perhaps with the exception of the coastal margin of the south, the process of sedimentation was entirely interrupted at the close of the Jurassaic, for there are no marine sedimentary formations known that correspond to the marine Cretaceous or Tertiary, as shown by rocks of these systems from other continents. The limited development of rocks of the Tertiary age includes coarse conglomerates, the pebbles of which have been derived mainly from limestones, igneous intrusions, and volcanic eruptions, and perhaps in addition, part of the loess is confined to northern China. The extent and character of this formation will be described in detail in a later chapter.

The Quaternary.

There is no sharp dividing line between the deposits of Tertiary and Quaternary ages. The accumulation of the loess, alluvium, sands, pebbles, and of the ordinary soils of the Quaternary undoubtedly has continued from the Tertiary to the present time. The Tertiary was characterized by Mountain building, by local volcanic activity, and by widespread erosion, whereas, the Quaternary was distinguished by continental building.



			Feet	Meters	
Quaternary	Huang-t'u Formation		0-230+	0-70+	Loess with beds of gravel and sand
	Unconformity				
Upper Carboniferous	Shan-si formation		700+	210+	Sandstone and shale with numerous thin coal seams; rorks mosely buff, green brown or black
	Unconformity				
Cambro-Odovician (Sinian)	Ki-chou formation		2,500+	760+	Uniform dark limestone in massive beds, rarely associated with gray shales.
			400+	120+	Gray limestone in part shaly. Locally conglomeratic and oolitic
Algonkian	Man-t'o shale	Cm	180 to 350	55 to 110	Red shales with impure limestone and conglomerate.
	Unconformity				
	Hu-t'o series	Ah			Gray slates and limestones.
	Wu-t'ai series	AW			Schists, quartzites, and marble.
Archean	T'ai-shan complex	Art			Gneiss, schists, and granite.
	Total thickness of Paleozoic strata		3,550 to 3950	1,020 to 1,130	

GENERALIZED SECTION OF ROCKS OF WU-T'AI DISTRICT, SHAN-SI.

(After Eliot Blackwelder)

CHAPTER IV.

ARCHEO-PROTEROZOIC.

In the preceding chapter, the term Archean has been assumed to embrace all those rocks formed prior to the Paleozoic era. But as this chapter is devoted to correlation, a discrimination, on the basis of marked characters, is necessary in order that the facts may be more intelligently discussed. The term Archean is here applied to a fundamental basement of rocks, characterized by its extreme complexity of geological relations and the absence of fossils. On the other hand, formations which are more distinctly of a sedimentary character and which overlie the Archean rocks but are beneath those of Paleozoic age, are included under the term Proterozoic. By such definition of these terms, the T'ai-shan complex of China is appropriately assigned to the Archean and is equivalent to the Keewatin formation penetrated by the Laurentian gneisses and granites of Canada, while the Proterozoic is equivalent to post-Laurentian-pre-Cambrian rocks.

The Archean.

The T'ai-shan complex embraces a group of rocks that display very intricate geological relationships and consist for the most part of gneisses and schists with subordinate intrusion of granites, basalts, and other igneous rock types, often associated with local developments of sedimentary rocks, In general, the rocks belonging to this complex are highly metamorphosed. In the majority of cases, study of thin sections has shown that the gneisses from different localities within the T'ai-shan complex of China have resulted from the metamorphism of granites, and that the schists have developed from the gneisses. Dykes and small bodies of younger granite and other intrusive rocks traverse the gneisses and schists, and seldom display evidences of having been subjected to processes of metamorphism. This fact may be explained by the belief that these unmetamorphosed bodies were injected after the ancient diastrophism.

The exposed areas of Archean rocks in China are not comparable in extent with those of America and Europe. In China, these exposures are almost wholly confined to the north. In the south, the Archean has come to view only in the provinces of Hu-nan and Hu-peh, and in some of the passes among the mountains of the south-west. The northern localities, where this complex has been best dismantled, are in Shan-tung, Chih-li, and Shan-si.

In the province of Shan-tung, the Archean is broadly exposed in the T'ai-shan or Table mountain. In the same region, the complex varies in petrographical character in different localities, but in general, it comprises one or more varieties of gneiss, one or more schists, one or more of granites, together with pegmatite dykes and veins of quartz. The minor intrusives form a reticulating network of dykes and small bodies cutting the more highly metamorphosed rocks. In some cases, the granites surround areas underlain by gneisses and schists, while schistose bands traverse the gneisses.

The T'ai-shan complex is prominently developed in western Chih-li in the vicinity of T'ang-hien and F'ou-ping-hien. In this district, the basal mass is composed of gneisses and schists which have been intruded by many dykes. Some of these dykes are more or less metamorphic in appearance. In addition to the intrusives, there are rocks of sedimentary origin. The prevailing gneiss is a quartzose rock in which the dark mineral is either biotite or hornblende, and in which augen have occasionally been developed. Moreover, lenticular masses of amphibole-and biotite-schists varying from a few inches to many feet in length are almost invariably found embedded in the gneisses. In many localities, however, mica-gneiss graduates into a mica-schist. But in Chih-li, as in Shan-tung, the constituents of the complex vary from place to place. For instance, on the northern slope of the mountain, about three miles northeast of T'ang-hien, the gneiss is found in association with muscovite-and biotite-schists and coarse-grained marble. In the same region, sericite-schists, amphibolites and other rocks, originally of sedimentary character, are known to occur with highly quartzose gneiss. In this region, the younger intrusives intersecting the gneisses and schists are represented by granites, aplites, granite-porphyries, felspar-porphyries, and altered basic rocks - the greenstones.

In northern Shan-si, the T'ai-shan complex is fundamentally the same in general character as that in western Chih-li. In fact, the former is but the continuation of the latter. The best exposures of this complex are in the Wu-t'ai range, where it underlies two systems of metamorphic sediments - the Wu-t'ai and the Hu-t'o systems. In reality, the Wu-t'ai underlies the Hu-t'o, but on account of the severely metamorphosed character of the rocks in that region, the two systems cannot be easily distinguished. The Wu-t'ai system consists principally of schists, quartzites, and marble; the Hu-t'o system of gray slates and marble.

Correlation.

From the foregoing descriptions, it is seen that in its development, in its constitution, and in its relation to younger formation, the ancient complex in Shan-tung, in Shan-si, and in Chih-li is remarkably uniform. It is a true basement underlain by no other formation, but underlying either the Proterozoic or the Paleozoic strata. This is true not only in the case of the Archean in China, but is equally true of the Archean in other continents. This truth may be better revealed by the following:-

Locality	Local Name of Formation	Character.
China	T'ai-shan complex	Basal; gneisses, schists, granites, quartzites, intruded by igneous masses in the form of dykes and veins; occasionally accompanied by rocks of sedimentary origin; the intrusives and the sedimentaries may also have been metamorphosed.
North America	Keewatin (Intrusive contact) Laurentian	Basal; chiefly of coarse red, gray, banded felspathic, amphibolitic, pyroxenic, or micaceous gneisses, accompanied by pegmatites and limestones.
Scotland	Lewisian	Basal; amphibolitic gneiss, amphibolitic schists, mica-schist, accompanied by bands of limestone and other crystalline rocks; traversed by veins of pegmatite and quartz.
Scandinavia	Archean Rocks	Basal; red and gray granites, often gneissoid; banded gneiss, garnet-gneiss, mica-gneiss, mica-schist, often accompanied by gabbro, gabbro-diorite and hyperite, some sedimentary rocks, as quartzites, etc.
Central Europe	Archean Rocks	Basal; red gneiss, gray gneiss, mica-schist, granite, often in association with graphitic limestone and serpentine.
India	Archean Rocks	Basal; gneisses and schists of various sorts.

The Proterozoic.

The Proterozoic in China consists of two distinct systems. These are the Wu-t'ai and the Hu-t'o. From their stratigraphic position and petrographical character, Bailey Willis considered these two systems to be equivalent to the three main series of the so-called Algonkian of America - the Huronian (lower and middle), the Animikean (upper-Huronian), and the Keweenawan. The best development of these rocks is displayed in Northern Shan-si, in the Wu-t'ai range and its vicinity.

The Wu-t'ai System.

In the Wu-t'ai range, the Wu-t'ai system appears lying unconformably upon the T'ai-shan complex, and within this region, the Wu-t'ai itself is naturally subdivided by three unconformities into three series. At the base lies the Shi-tsui series which is composed principally of mica-schists, gneisses, magnetitic quartzite, and felspathic quartizites. The rocks of this series are best exhibited in a monocline along the T'ai-shan-ho, southeast of Shi-tsui. The felspathic quartzites in association with dark mica-schists and pure quartzite constitute the southern portion of the section; the mica-schists and fine-grained gneisses with other rocks form the middle segment; and the magnetic-quartzite with jaspillite make up the southern end. According to Bailey Willis, in a ravine south of the T'ai-shan-ho, a peculiar quartzite, which is believed to be a recrystallized arkose, containing large crystals of red felspar, occurs at or near the base of the Shi-tsui series, on or close to the T'ai-shan gneiss, from which the material might have been derived by erosion. The origin of the immediately underlying stratum of mica-schist is indeterminable. In his description, Bailey Willis states in part: "The felspathic quartzite grades upward through quartzite containing some mica and but little felspar into mica-schists, which present great variety of mineralogical composition and are in turn succeeded by quartzites which are in part magnetic. The section of sediments, which has a length of eight miles, interrupted by a mass of augen-gneiss that is probably intrusive. The dip of the Shi-tsui strata in this section is from 30 degrees to 70 degrees to the northwest, and the repetition of the quartzite on two sides of a great body of mica-schists is such that the probable structure is a syncline overturned toward the southwest."

The Nan-t'ai series rests unconformably upon the Shi-tsui. It comes to view in the southern peak of the Wu-t'ai range where it is composed chiefly of siliceous marble, gray to black or red quartzites, and chlorite-and muscovite-schists. Garnet and stourolite are invariably present.

The Si-t'ai series is also separated from the Nan-t'ai by an unconformity. It includes chlorite schists, magnetitic quartzites, and a conglomerate. This group of rocks constitutes for the most part the northern slope of the Wu-t'ai range. The unconformity between the Nan-t'ai and the Si-t'ai is well exhibited in the Canyons on the southern slope of this range. There, its position is marked by the presence of a folded stratum of basal conglomerate which is chiefly composed of pebbles of quartz and quartzite.

The Hu-t'o System.

In the district of Wu-t'ai hien, in Northern Shan-si, there appears a group of rocks which differ radically from those of the Wu-t'ai system; in that they are much less metamorphosed and entirely sedimentary in origin. The rocks are conglomerate, quartzite, shale, and limestone, which nearly resemble the Lower Sinian, but the latter is separated from the former by an unconformity and by the presence of fossils. Being best exposed along the Hu-t'o River where it occurs as a synclinorium, this group of rocks has been called the Hu-t'ai system. This system may be divided into two series, on the basis of the predominance of limestone in the one and slate in the other. These have been designated as the T'ou-tsun series and the Tung-yu series.

The lower T'ou-tsun series ranges in thickness from 1000 to 1800 meters. The beds are principally composed of earthy-gray to purplish slates with thin layers of buff to pink dolomite and siliceous limestone. The lowest beds, however, are composed of quartzite with local layers of conglomerate.

The Tung-yu series includes gray limestone in which chert is present in considerable quantity, and intercalated thin bands of gray to red slates or phyllites. The thickness of this series is about 900 meters.

A geological section, drawn by Eliot Blackwelder, of the Wu-t'ai system, observed on the T'ai-shan-ho, extending from southeast to northwest across the southeastern slope of the Wu-t'ai-shan, shows that there are no less than 32 different rock varieties ~~formations~~ in the succession. These include different varieties of biotite gneiss, mica-and chlorite-schists, quartzites, arkoses, conglomerate, amphibolites, and marble. The region has been highly folded. The metamorphosed sedimentaries are here and there cut by younger intrusions of granite and numerous dykes of black schistose amphibolites, or greenstones, varying from 20 to 100 feet in width. The greenstone dykes intersect both the T'ai-shan gneisses and the Wu-t'ai schists, while similar dykes have been observed penetrating the younger Hu-t'o series.

Correlation.

Stratigraphically, the Proterozoic in China bears a close analogy with the Proterozoic in America. Bailey Willis has concluded that the Lower Wu-t'ai (Shi-tsui series) rests unconformably upon the T'ai-shan complex, as does the Lower Huronian upon the Keewatin. The Middle Wu-t'ai (Nan-t'ai series) lies unconformably upon the Shi-tsui as does the

Middle Huronian on the Lower Huronian. The Upper Wu-t'ai (Si-t'ai series) is separated from the Middle Wu-t'ai by an unconformity as is the Upper Huronian (Animikie) from the Middle Huronian. The stratigraphic relationship between the Hu-t'o system and the Wu-t'ai system is somewhat similar to that between the Keweenawan and the Huronian. Petrographically, however, the identity fails utterly from the fact that the Hu-t'ai is composed entirely of sediments, while the Keweenawan comprises basic lava flows, interbedded with minor thicknesses of sandstone and conglomerate. On the basis of diastrophism, chiefly reflected by the relative importance of the unconformities within the proterozoic rocks, Dr. Frank D. Adams has concluded that the three series (the Shi-tsui, the Nan-t'ai, and the Si-t'ai) of the Wu-t'ai system are probably equivalent to the Lower and Middle Huronians, and that the two series (the T'ou-t'sun, and the Tung-yu) of the Hu-t'o system to be correlated to the Upper Huronian (Animikie-Nastapoka) and the Keweenawan.

The Stratigraphic succession and petrographical character of the pre-Cambrian rocks of China and of North America are compared in the following table:-

Era	CHINA			AMERICA		
	System	Series	Character	System	Series	Character
Proter-ozoic	Hu-t'o	Tung-yu	Slates, limestones		Keweenawan Athabasca	Essentially of lava flows
						Unconformity slight
		T'ou-t'sun	Slates & quartzite		Upper Huronian or Animiki-Nastapoka	Quartzites, slate, iron formation, & both extrusive & intrusive sheets of diabase
			Unconformity great			Unconformity, great
	Wu-t'ai	Si-t'ai	Chiefly of chlorite-schist, quartzite, and conglomerate at the base	Huron-ian	Middle	Arkose, gray wacke, quartzite, and slate
			Unconformity slight			
		Nan-t'ai	Chiefly of silicious marble, jasper quartz-ite, and schists.			Unconformity slight
			Unconformity slight			
		Shi-tsui	Chiefly of mica-schists, gneiss, quartz-ite, and felspathic quartzite.		Lower	Chiefly of schists slate, limestone, and quartzite, with subordinates of iron ores & jasper.
	Unconformity, great			Unconformity, great		
Archean	T'ai-shan Complex			Keewatin (Intrusive contact) Laurentian		

CHAPTER V.

COAL.

Introduction

The Chinese word tan, written 炭 . is applied to charcoal or to ordinary coal. To avoid confusion, the Chinese more generally call ordinary coal mei-ten (soot-coal), while coal possessing an appearance like that of a rock or stone is designated shih-tan (rock or stone-coal). The word tan itself is made up of three particles, namely, 火 (fire) (bank, cliff, or shore), and 山 (mountain). There are two possible interpretations of the derivation of 炭 . It originated either because charcoal had been obtained by the ancients through the burning of wood beneath cliffs in the mountains, or because the ancients knew of a certain substance (coal) obtained from beneath banks, cliffs, shores, or mountains that proved to be combustible.

In so far as the writer has been able to learn, there is no special record to show when coal was first utilized as fuel in China, but from various sources, it is known to have been used as fuel for many centuries. It has been the practice of the Chinese to have their seats of government established, if possible, upon sites beneath or near which coal was supposed to exist in order that in time of invasion, the inhabitants might not be deprived of a supply of fuel. Moreover, the nature or properties of coal were often mentioned in the literature and in the government records of the ancient Chinese. The Geographical Record of the Former Han (dynasty, 201 B.C. - 25 A.D.), contains this statement, "In the Yu-Chang district, there is combustible rock which may be used as fuel."

Any attempt to sketch the history of the coal industry of China meets with almost complete failure, because in time past no statistical records were kept concerning the coal production of the country. However, it is definitely known that the Chinese have mined their coal for centuries to supply their own needs. Within late years, through the introduction of modern methods of mining, the output of coal has been increased very rapidly, and for several years, China has been able to maintain her imports of coal at an approximately constant tonnage, while her exports of coal have been increased. This is witnessed by the following data:- *

Year	Export	Import
1907	6,351 tons	1,403,472 tons
1908	27,894 "	1,504,549 "
1909	195,950 "	1,516,629 "

* Kinosuke Inouye, The Coal Resources of China, Coal Resources of the World, International Geological Congress, 1913.

* In 1912, Prof. T.T.Read of the University of Peiyang gave the following estimate of the annual coal production of China:-

Province	Anthracite	Bituminous	Sub-bituminous and lignite.
	Tons	Tons	Tons
Manchuria	———	25,000	1,000,000
Chihli	840,000	2,090,000	150,000
Shansi	4,000,000	25,000	———
Shensi	———	500,000	———
Kansu	———	500,000	———
Shantung	300,000	500,000	———
Honan	1,000,000	———	———
Szechuan	———	500,000	———
Kueichow	———	250,000	———
Yunnan	———	300,000	———
Chekiang	———	10,000	———
Kiangsi	———	700,000	———
Hunan	———	200,000	———
Kuangtung	———	50,000	———
Kuangsi	———	100,000	———
Other provinces	———	100,000	———
Total	6,140,000	5,900,000	1,150,000
	5,900,000		
	1,150,000		
Grand Total	13,190,000.		

In his paper on the Coal Resources of China, Kinouske Inouye estimates that the annual production of coal amounts to between 15,000,000 and 20,000,000 tons.

---

* T. T. Read, China Year Book, 1913.

The following table prepared by Noah Fields Drake gives the names of the more important coal mining companies that were operating in the country in the years 1911 and 1912 and their annual production:-

Locality	Name of Company	Nationality of the Co.	Output 1911	Output 1912
MANCHURIA--				
Fu Shun......	.South Manchuria Railway Co.	.Japanese....	1,186,600	1,600,000*
Pon Hsi Hu..	....	.Sino-Japanese	....	200,000*
CHIHLI--				
Chi Min Shan	.Chi Min Shan..... Colliery	.Chinese....	....	40,000*
K'ai P'ing Coal-Field.	.Chinese Eng. &.. Mining Co.	.British.....	1,170,163	1,453,540
K'ai P'ing.. Coal-Field	.Lan Cho Mining.. Co.	.Chinese....	....	300,000*
Ching Hsing.	.Ching Ching Min. Co.	.Sino-German	..198,000	350,000*
Lin Cheng...	....	.Chinese....	....	200,000*
SHANSI--				
Yang Chuan..	.Pao Chin Mining.	.Chinese....	....	75,000*
HONAN--				
20 miles west of Chang Te Fu.	.Liu Ho Kao Min.. Co.	.Sino-German	....	75,000*
Jai-mei-sen.	.Peking Syndicate	.British....	....	500,000*
SHANTUNG--				
Fangtse & Hung Shan....	Shantung Bergbau . Coal Co.	.German......	..500,000*	600,000*
Yi Hsien....	.Chung Hsing Min. Co.	.Chinese.....	..160,000	200,000*
KIANGSI--				
P'ing Hsiang	.Han Yeh Ping Iron & Coal Co	.Chinese.....	..700,000*	800,000*
KUANGSI--				
Ho Hsien....	....	.Chinese....	....	No data
Total about	....			6,393,540

* Estimated.

China is renowned for her richness in coal deposits. None of her provinces are known to be without coal fields, but the various provinces naturally differ in the amount of their coal reserves. There are two great groups of coal-fields in the country—the northern and the southern fields. The former comprises most of southern Shan-si and the adjacent parts of Chih-li and Ho-nan; the latter covers the entire province of Kwei-chou and large portions of Sze-ch'uan, Yun-nan, and Kwang-si, that are adjacent to Kwei-chou. Aside from these, there are many smaller coal fields of great importance, some of which will be described in this chapter.

The coal deposits of China were formed during the Carboniferous, Permo-Triassic and Jurassic periods. Those of the Carboniferous lie chiefly in the north, while the coal of southern China is in major part of either Permo-Triassic or Jurassic age. In the Chinese fields, three principal varieties of coal have been recognized--bituminous coal, anthracite, and lignite. The last is insignificant in quantity. The more important fields yielding anthractite lie in the north, in the provinces of Shan-si, Chih-li, and Ho-nan; the less important in the south, in the provinces of Hu-nan, Hu-peh, Fuh-kien, and Kwang-tung. The Shan-si fields are the largest of all; those in Chih-li and Ho-nan are next in importance. The Shan-tung fields yield both anthracite and bituminous coal. The anthracite is worked by thousands of small mines scattered throughout the country, and is used especially as fuel in the household and in the burning of lime.

Bituminous coal is distributed in every province and has been worked considerably by modern methods. The well-known fields of this variety of coal are the K'ai-p'ing, Chin-hsing, Lin-ch'eng, and P'ing-hsing. The bituminous coal is known to be of good quality and in many localities it is suitable for the manufacture of coke. The composition of the coal varies in different fields. The following illustrates the differences in composition:

Locality	In 100 Parts of the Original Coal				
	Water	Volatile Hydro-Carbons	Fixed Carbon	Ash	Sulphur
	%	%	%	%	%
CHIHLI--					
Hsin Chiu Coal-field	9.97	32.41	45.78	11.88	1.91
Pei P'iao Coal-Field	3.25	32.00	58.65	6.10	
Nan P'iao Coal-Field	2.50	31.00	57,50	6.50	
P.ing K'Ou Coal-Field		48.00	46.00	6.00	0.76
Wang P'ing " "	2.67	4.08	82.64	10.59	0.36
Fang Shan " "	5.11	6.83	72.14	15.91	0.17
Chai T'ong " "	1.20	21.54	71.14	6.11	1.05
Chai T'ong " "	3.62	5.31	84.93	6.13	0.43
K'ai P'ing " "	1.00	26.00	58.00	15.00	1.00
Hsuan Hua " "	3.49	15.93	72.49	8.07	0.10
Hsuan Hua " "	1.16	3.21	83.19	12.43	0.10
Ching Hsing " "	0.89	27.97	61.04	9.64	1.45
SHANTUNG--					
Yi Hsien " "	0.52	28.60	63.31	7.05	0.52
SHANSI--					
Tse Chou " "	2.26	3.43	84.66	9.63	0.36
P'ing Yao,S.W.Shansi	0.49	17.81	57.70	23.98	2.80
Yang Chuan,S.E. "	1.78	7.62	80.93	9.66	1.40
Ch'in Shui S.E. "	1.28	9.79	89.06	11.60	1.80
Ta Tung Coal-Field	4.45	30.17	65.38	4.06	1.29
Saratsi Coal-Field	1.16	29.38	69.46	6.97	0.78
HONAN--					
Chang Ho Coal-Field	0.79	14.16	75.09	9.95	0.58
Jai-mei-sen " "		6 to 7	84.50	10.00	

Locality	Water	Volatile Hydro-Carbons	Fixed Carbon	Ash	Sulphur
	In100 Parts of the Original Coal				
ANHUI—					
Ch'i Cho Coal-Field	13.00		73.00	14.00	
CHEKIANG—					
Tung Lu Coal-Field	2.10	4.41	70.74	22.74	
KUANG TUNG—					
Lien Chou Coal-Field	1.09	15.00	66.46	17.44	3.07
Tung Shui Coal-Field	0.80	10.47	67.62	21.11	4.37
Che Ku Sheck" "	I,07	7.63	85.25	6.04	0.89
Mei Shan " "	0.79	9.34	83.45	6.41	1.06
HUNAN—					
Mei T'ien S.Hunan	1.84	6.32	82.58	9.26	0.73
KUEICHOU—					
S.W.Kueichou	0.80	9.50		35.00	
Near Kouei Yang	0.60	12.80		8.80	

Without question the coal resources of China are very vast, but the available tonnage has not been estimated accurately because a careful geological study has not been made of these deposits. Therefore the estimation of the coal reserves made by different persons do not agree. The following estimation is taken from Prof. Noah Field Drake's Paper on "The Coal Resources of China", published by the International Geological Conference that met in Canada in 1913:

	Metric Tons.
Mongolia	1,200,000,000
Chihli	22,668,000,000
Shantung	7,083,000,000
Shansi	714,340,000,000
Shensi	1,050,000,000
Kansu	5,129,000,000
Honan	9,275,000,000
Kiangsu	10,000,000
Anhui	187,000,000
Hupei	117,000,000
Chekiang	24,700,000
Fukien	25,000,000

(Estimation Continued)	Metric Tons
Kiangsi	3,395,000,000
Kuangtung	1,009,000,000
Kuangsi	500,000,000
Hunan	90,000,000,000
Szechuan	80,500,000,000
Kueichou	30,000,000,000
Yunnan	30,100,000,000
Total	996,612,700,000

Conclusion

From the foregoing, it is seen that China's (including Mongolia) coal deposits are enormous, although the various estimates of her coal resources may not be reliable; but the chances are that the estimates are too small rather than too large, since they were calculated from a known basis. There is good reason to believe that some coal areas will yet be discovered.

In the preceding table Drake estimates that the coal reserves of China proper and Mongolia amount to 996,612,700,000 metric tons. Basing an evaluation upon the present price of coal, these reserves are certainly worth several trillions of dollars. Drake's estimate of the coal reserves includes only the coal deposits now known in China and Mongolia. In addition, it has been estimated by Inouye that Manchuria possesses 800,000,000 metric tons of probable coal reserves. One should also emphasize the possible discovery of coal in Tibet (area of 463,320 sq.miles) and in Chinese Turkestan (area of 550,579 sq.miles).

The time will come when capital will be attracted to develop these enormous coal deposits, and this gift of nature, the greatest mineral gift that the Chinese Republic possesses, will sooner or later be turned into real wealth(in the strict economic sense). Accompanying this development, numerous and varied industries will be established, and new phases of life will be awakened. It is impossible within the scope of this paper to describe all of the well-known coal-fields in the country. In order that the reader may gain a general conception of the wealth of coal in China, a few of the more typical coal fields are described in the following pages:-

K'ai-p'ing Coal-Field.

The K'ai-p'ing coal-field is situated about five miles northeast of Tien-tsin in Chih-li province. It comprises a synclinal basin more than 20 miles in length which for the most part, lies within the coastal plain; it is thus largely covered by alluvium and loess. The lowest coal seam lies about 250 feet above the Carboniferous limestone. Within the succeeding 400 feet, several coal seams are interstratified with shales and sandstones. At Tang-shan, 13 seams, with an aggregate thickness of 85 feet are known to exist. The coal is suitable for the manufacture of excellent coke. The aggregate thickness of the coal varies in different sections of the field. At Tang-shan, in the southwestern end of the basin, the total thickness of the workable coal varies from 50 to 60 feet; at Ma-Chia-k'ou, 60 to 80 feet; at Chao-ke-chuang, 80 to about 90 feet; and at Lin-hsi, northeast end, from about 40 to 50 feet. Within this field, the rocks enclosing the coal dip from about 20 degrees to almost 90 degrees, but dips near 50 degrees predominate. Prof. Drake estimated the actual reserves of the area to be 1,641,000,000 tons, and the probable reserves as 2,757,000,000 tons. His average analysis of the coal shows:-

Volatile hydro-carbons	26%
Fixed carbon	58%
Ash	15%
Water	1%
Sulphur	1%

The coal in this field has been worked since the Ming dynasty (1368-1644 A.D.), and here modern methods of mining were first employed in China. In 1879, at T'ang-shan a modemn shaft was sunk by the Chinese. The T'ang-shan pit is said to be the largest in the country. According to the estimate of Inouye, from 1881 to 1909, the total amount of coal mined within the K'ai-p'ing coal field was 161,000,000 tons. The annual yield is approximately 1,159,000 tons.

Shan-si Coal-Fields

Upon hearing the announcement by Baron von Richthofen concerning the enormous coal deposits that he observed some forty years ago in Shan-si, China, the world was at once relieved from the reasonable worry concerning the approaching exhaustion of known coal supplies. It has been said that the coal fields of Shan-si alone would be sufficient to meet the consumption of coal by the entire world for a period of one thousand years. This is probably an exaggeration since recent researches show that Richthofen's estimate of the deposits is too large. He estimated that the eastern half of southern Shan-si alone could produce 630 "Millionen den Tonnen" (630,000,000,000 tons) of anthracite.

Of the total coal reserves of China and Mongolia just mentioned (996,612,700,000 English tons) 714,340,000,000 tons are assigned to Shan-si province. The fields containing these reserves are numerous and they are chiefly confined to the southern half of the province; only two coal fields are present in the northern half. The northern deposits are of Jurassic age, while those of the south belong to the Carboniferous. Richthofen regarded the coal deposits of Southern Shan-si as divisible into two distinct fields,--the eastern or anthracite field, comprising an area of 13,500 square miles, and underlain by an average thickness of 40 feet of anthracite, and the western or bituminous field with an area of 21,000 square miles containing an average thickness of 25 feet of bituminous coal. According to Prof. Drake's researches, the coal deposits in the eastern field include three varieties, viz'. anthracite, semi-anthracite and bituminous. His estimate for both the actual and the probable coal reserves in the two fields is given in the following tables:-

South-eastern Field

Actual Reserves		Probable Reserves	
Area	12,000 sq. miles	Area	13,000 sq. miles
Average thickness	25 feet	Average thickness	30 feet.
Anthracite:	about 120,000,000,000 tons	Anthracite:	about 150,000,000,000 tons
Semi-anthracite:	about 120,000,000,000 tons	Semi-anthracite:	about 150,000,000,000 tons
Bituminous Coal:	about 120,000,000,000 tons	Bituminous coal:	about 150,000,000,000 tons.

South-western Field

Area 10,000 sq. miles.
Average thickness, 25 feet.
Probable reserves of bituminous coal 255,890,000,000 tons.

In general, the coal seams in this southern region are enclosed within sandstones and shales resting unconformably upon Sinian limestones. Southern Shan-si is an elevated plateau deeply dissected by streams whose valleys are from 2000 to 4000 feet above the coastal plain while the hilly parts rise from 4000 to 7000 feet above the plains. Over by far the most of the area, the Sinian limestones and the Carboniferous formations lie almost horizontally. Hence the coal seams can be worked with relative ease and without loss of coal. In the southeastern field, the coal is frequently exposed on the sides of the valleys, while in the south-western field, the coal-bearing formation is more generally concealed by loess which varies from a few feet to several hundred feet in thickness. Hence, in this portion of the province, exposures of coal seams are restricted almost entirely to the valleys of those rivers that have cut through the blanket of loess.

Coal Mines in the Eastern Field:-

In many places in the eastern coal field, coal mines, operated according to modern methods, have been reported. In Kinosuke Inouye's report published in 1913, the following localities are enumerated: In Nan-ts'un, coal-seams with an aggregate thickness of about 30 feet have been worked by a shaft to a depth of 300 feet. Hard anthracite imbedded in undulatory strata of the Carboniferous has been mined in Sun-ts'un and Chang-ling to the northeast and west of

Tse-chou-fu, to a depth of over 200 feet. The thickness of the coal varies from 14 to 24 feet. In Shu-yuan-t'ou, Li-ch'uan, Ta-cli, Wu-men, Sze-ma-shan and Erk-shih-li-p'u, coal having a thickness of from 12 to 30 feet has been mined. The amount of coal taken from the neighbourhood of Tse-chou has been estimated to be 2,000,000 tons.

In P'ing-ting-fu which is situated in the northern part of the eastern field, important coal seams lying 200 to 300 feet below the surface have been worked at many places north and south of the P'ing-t'an river by a China Company. The thickness of the coal varies at different places from 9 to 18 feet. In addition, this company has also operated coal mines at Mai-ti-kou, Chuang-Chuang-kou, Tieh-lu-kou, Yen-Tzu-kou., etc., and produced in 1908, 2,200 tons; in 1909, 5,600 tons; in 1911, 21,000 tons. There have been many more mines that have been operated on a small scale in this great field.

Coal Mines in the Western Field:

In this great field, coal has been mined in many localities, but no data of the output is accessible. In Yu-tsze-hien the coal outcrops in twelve places, but only one mine has been opened in this district. The coal is said to be 18 feet in thickness. K'u-nan-shan and P'ai-chien-k'u are also important localities where coal is known to occur in large quantity.

Ta-Tung-fu Coal-field:

This coal field lies in the northern part of Shan-si, near the city of Ta-tung-fu. According to Richthofen, its area is about twenty-seven square miles, and it is underlain by several seams of coal, the most important of which has a thickness of from 20 to 30 feet. But Dobbins has reported that in this region there are two fields, one about thirteen miles northwest and the other thirty miles southeast of Ta-tung-fu. The area of the first is about 20 square miles. In one of the mines, four coal seams are present that are separated from one another by about three feet of shale. As stated previously, the coal-bearing strata in this district are of Jurassic age. Prof. Drake has estimated the reserves of this field to be: Actual reserves of bituminous coal about 3,060,000,000 tons; probable reserves of bituminous coal about 8,200,000,000 tons.

Ho-nan Coal-Fields:

Mention has been made elsewhere in this chapter that the great northern coal-field covers the southern part of Shan-si, the southwestern of Chih-li, and the extreme northern part of Ho-nan. The coal deposits in the extreme north of Ho-nan are but the continuation of the great Shan-si field. Prof. Drake, who has spent considerable time in the study of the coal areas of Ho-nan, has described the coal fields of that province as lying within areas that have been affected by block faulting and foldings. According to him, in the extreme north, most of the coal occurs in fault blocks, at the edge of the coastal plains and along the border of the southeastern coal-field of Shan-si. A considerable part of the blocks of coal-bearing beds are covered by the loess and alluvium of the coastal plains. The extent of these coal-bearing blocks is not definitely known but it is believed that they extend from the northern border of Ho-nan to a point southwest of Hwai-Ching-fu, a distance of 150 miles. This belt is composed of from one to three or four strips or blocks of coal-bearing beds. The principal strip varies in width from one to two miles or more. The coal-bearing strata are of Permo-Carboniferous age, and the total thickness of the coal seams is probably 20 feet. The coal-deposits in this belt have been mined at Jai-mei-sen, Pai-shan, Ch'ang, Chiao-cha, etc. The coal from the extreme north of this belt is bituminous in character but that from farther to the south is anthracite. The reserves of the entire province have been estimated to be 90,000,000,000 tons.

Sze-Ch'uan Field:

As noted previously, the Kwei-chou coal field extends into Sze-ch'uan, where it covers all the south-eastern part of the province. Here the coal-bearing strata lie upon the Sinian limestone. The total coal-bearing area of the entire province is deemed to be not less than 50,000 or 60,000 square miles, but it is only within 15,000 square miles where through folding of the rocks, the coal seams have been made available for mining at depths of less than 4000 feet. Very little is known concerning the thickness of the coal seams within this area. The coal occurs as Carboniferous, Triassoc and Jurassic formations. In Yueh-sui, anthracite has been found in a formation which has been reported to be of Silurian age(?); it is non-coking and of inferior quality. In the eastern corner of this province along the Ta-ning-ho, northwest of Ta-ning-hien, where the coal has been mined on the river(Ta-ning-ho), the coal-bearing formation is observed to consist of gray limestone with intercalated shale, forming a syncline along the river. The coal is found both in the shale and limestone and its thickness varies from 3 to 4 feet. In this province, three varieties of coal are known--lignite, bituminous, and anthracite. The reserves of this province have been estimated as follows:-

Lignite	500,000,000	tons
Bituminous	60,000,000,000	"
Anthracite	20,000,000,000	"

Kwei-Chou:

In the province of Kwei-chou, it is believed that there are not less than 50,000 square miles underlain by coal-bearing formations and not less than 10,000 square miles of workable seams with an average thickness of about 3 feet. The coal-bearing formations are known to belong to the Carboniferous, Triassic and Rhaitic ages. Anthracite, semi-anthracite and bituminous coal are all known to occur within this field. In An-shun-fu and in Kwei-yang-fu, the coal has been worked actively. The reserves of this province are believed to be 30,000,000,000 tons.

Yu-nan:

Easten Yu-nan is covered by the continuation of the Kwei-chou coal-field. But here the coal-bearing formations are also represented by the Pliocene. The Pliocene coals are of lignitic varieties. Coals of the Paleozoic age are bituminous in character. The coal-bearing area is probably not less than 30,000 square miles. In this province, Leclere reported the presence of Palaeozoic coal in the following localities: In a short distance to the northwest of Yun-nan-fu, coal about one meter thick has been found lying in an almost horizontal position; about forty miles southwest of Yun-nan-fu, at Lou-leang, three or four seams of bituminous coal, from 1½ to 2 meters thick, occur in beds of sandstone differing at high angles; about 20 miles northeast of Yun-nan-fu a bed of bituminous coal about one meter in thickness has been observed. At Cha-ko, about ten miles north of Tung-chuan, in northeast Yun-nan, coal seams, 3 to 4 meters thick, have been found interbedded with shale. Lauteuois states that Palaeozoic coal has been observed in the following localities within this province:-

(1) "Tong Hai" coal-beds, thickness of coal-bed from 0.2 to 1.0 metre;

(2) "Pe-tchen coal-bed, thickness 30 to 40 centimetres;

(3) Konen-iang coal-beds, one bed about 1 metre thick, and another about 1.7 meters thick;

(4) "Y-leang" coal-beds, two beds, one about 1 metre thick, and the other about 2½ meters thick.

Lantenois also gives the following list of localities where lignite is known to occur:-

(1) "Lam-ty" valley coal-beds; thickness 1½ meters to probably 12 meters.

(2) "Yen-fen-tchouang" mine; five or six beds varying in thickness from 5 to 15 centimetres.

(3) "Mientien" and "Pe-kia-tchouang" mines; coal bed about ome metre in thickness.

(4) "Si-tchouang" mine; coal-bed five metres thick.

(5) Pow-tchoo-pa mine; thickness of coal (brown lignite), about 20 meters thick. Prof. Drake estimates the lignite reserve of the entire province to be 100,000,000 tons, and the total coal reserve for the province to be 30,000,000,000 tons.

CHAPTER VI.

IRON

Introduction

In the ancient writings of the Chinese, many references pertaining to the metal tieh or iron can be found. In the Record of Tributes of Yu (Yu, the Great, reigned 2205-2197 B.C.), iron, gold, silver and copper were mentioned as articles of tribute. The smelting of iron on a commercial basis was an early undertaking. In the Book of Economics, it is found that Kwo Tsung of Han-tan, Tsaow Liang of Lu, and Cho of Chaou (all lived under the Chou Dynasty, 1122-255 B.C.) became wealthy as smelters of iron. The preface of the poem Kiang Yen Tung Keen (The Bronze Sword of Kiang Yen) remarks, "Weapons of the antiquity were made of copper; but as in the time Tsin (dynasty, 221-206 B.C.), strifes were prevalent in the country and arms everywhere arose, copper was no longer sufficient to meet the demand, hence iron was employed to make up the deficiency."

From these and other references, it is known that the arts of smelting and casting were practiced by the Chinese long before the Christian era. But unfortunately, very little is known concerning their methods. This is due to the fact that the Record of Researches in Arts, is believed to have perished together with other classics in the Burning of the Books at the hand of Tsin Shih Hwang (reigned 221-209 B.C.). Since that time, the iron industry has attracted much public attention. In the time of the former Han dynasty, (201 B.C. - 25 A.D.), there existed a book containing sixty chapters, which was entitled A <u>Treatise on Salt and Iron.</u>

The literature of the later dynasties contains much information about iron and its related industries, but since the writer could not gain access to these Chinese books, it has not been possible to discuss the history of the development of iron mining and smelting in China as fully as seemed desirable. The progress of the iron industry during the past 500 years is more definitely known. According to T. T. Read, during the Ming dynasty (1368 to 1644 A.D.) iron mines were opened at Lung-tung in the province of Hu-peh, some 50 miles southeast of Han-kow. At Lung-tung, in the Ta-yeh district, some of the old slag is still lying on the dumps. During the Ming dynasty, attempts seem to have been made to work the property as a copper mine. The annual production of iron in the province of Shan-si, as estimated by von Richthofen in 1872, amounted to 160,000 tons. It should be noted that in the past the iron industry of China must have been centered in Shan-si, for in the southern portion of that province, abundant iron ores occur in proximity to very extensive coal deposits. As already pointed out in the preceding chapter, the coal in the southern Shan-si field includes both anthracite and bituminous varieties. The iron ores in that region are principally hematite and limonite, occurring as nodules in the shales and sandstones of the carboniferous system. In Lo p'ing, Shan-si province, as described by Richthofen, the iron was obtained by smelting the ore with coal in earthen crucibles assembled in pits.

The contents were heated for several days until a spongy mass was produced, and this was drawn out, treated again, and compressed into bars.

Twenty-two years later (1894), the total output of iron from Shan-si, as estimated by W. H. Shockley, amounted to 50,000 tons per annum. The decrease was due to the fact that, because of its inferior quality, the native product could not compete with foreign iron. For several years, prior to 1891, China imported much iron and exported iron ore, the most of which went to Japan. But in 1891 a modern smelting plant was erected at Han-yang in Hu-peh province by the Government. Since that time, China has exported both pig iron and iron ores. This Government establishment is now an exclusive Chinese stock company and is known as the Han Yeh Ping Iron and Coal Corporation, Limited. The Corporation's centres of activity are three—the coal mines at P'ing-hsing in the province of Kiang-si, over 300 miles south of Hanyang, the iron mines at Ta-yeh, about 50 miles southeast of Han-yang, and the steel works at Han-yang. The total number of employees in 1908 was about 20,000. According to T.T. Read, pig-iron from the Han-yang works had already been sold in the Atlantic and Pacific ports of the United States previous to 1908. The following are some of the Corporation's official reports:

Iron ores produced by the Ta-yeh mines in

1909	Magnetic ore,	306,000	tons
	Manganese "	1,500	"
1910	Magnetic ore,	303,000	"
1911	Iron ore	359,467	"

Exports for 1911:

	To Foreign Ports		To Chinese Ports			Tons
Iron ore	110,500	tons	20	tons	=	110,520
Pig-iron	51,300	"	26,128	"	=	77,428

More detailed statement for the year 1911-1912:

Pig iron Total Output		93,337 tons
Shipments to:		
Hankow and other Chinese ports		9,824
Japan		58,535
United States		4,465
Australia		5,765
Saigon		40
	Total	78,629
Rails Total Output		24,216 tons
Sale of rails and fastenings in China		23,492
Merchant bars, sales in China		1,250.

The total income for the year 1911 was 6,034,618.95 liangs (taels).

Distribution of Iron Ores

In China, less is known concerning the distribution of iron ores than of coal, but it is believed that iron-ore deposits are to be found in almost every province. Iron mining has only been carried on in those localities where iron and coal are found in close proximity. Little seems to be known concerning the mode of occurrence of the iron ores, and therefore the descriptions of the deposits as given in these pages are of a very general character. In so far as is known, the province of Shan-si contains the most important deposits of iron ore. Possibly, in comparison with other deposits, undue prominence has been given to the extent of the deposits of Shan-si, because of their favorable location in coal mining districts. Shockley states that the principal varieties of iron in this province are hematites and limonites, occurring in carboniferous shales and sandstones, as nodules varying in size usually from a few pounds to several hundred pounds in weight. Bedded deposits are also said to have been found. The following analyses of the iron ores of Shan-si are taken from E. T. Nystrom's paper on "The Coal and Mineral Resources of Shansi Province, China":

T'ai Yang Iron District.
Analysis, made by Mr.Edw.Riley, F.C.S. Lond.

Silica	4.07 %
Ferric Oxide	76.77 "
Alumin. "	3.46 "
Mangan. "	0,57 "
Calcium "	2.21 "
Phosphorus	0.25 "
Sulphur	0.074"
Carbonic Acid	9.37 "
Combined Water	0.59 "
Moisture	1.61 "
	98.974 %
Metallic Iron	53.88 "

Hu-peh.

In this province, iron ore has been worked most extensively at Ta-Yeh. Here the ores occur lying along the contact between a marble and a syenitic intrusine. The age of the marble is not definitely known, but it is believed to be of Sinian formation. The ore is principally hematite, replacing the limestone. Since 1891, mining has been carried on by the Han-Yeh Ping Iron and Coal Corporation. The deposits are very large. The ore exposed on the surface alone has been estimated as amounting to 500,000,000 tons. The iron content is high. The following analysis of the hematite from the Ta-yeh district was furnished to T.T.Read by the corporation:

Iron Ore, Ta-Yeh

Fe	60	to	62	%
P	0.05	"	0.25	%
S	0.05	"	0.12	%
SiO_2	3	"	5	%
Al_2O_3	1	"	2	%
Mn	0.2	"	0.4	%
Cu	0.05	"	0.25	%

Fu-kien.

A deposit of magnetite has been reported at An-khone, about 60 or 70 miles from Amoy. The quantity available is believed to be 10,000,000 tons, and the location is favorable for working.

Kwang-tung.

Iron ores are widely distributed in Kwang-tung province. They have been reported from Sin-hing-hien, Sin-ning-hien, Pon-yu-hien, etc. From Ma-On-Shan, some distance northeast of Victoria Island (the island of HongKong) occurrence of iron ore deposits has been reported by C. M. Weld. The ore-bearing body, consisting of pure magnetite, hematite, and "skarn" is found intercalated between quartzite and granite; at points, however, the ore lies between the granite and a mantle of soil and gravel. The ore-body is believed to be a replacement of an impure limestone or dolomite. The area, including the island of Hongkong, the peninsula of Kow-loon, and the New Territory, in which Ma-On-Shan is situated, comprises over 400 square miles and is underlain chiefly by granite with immense numbers of highly altered inclusions of sedimentary rocks of every size and shape. The northwest border of this area is exclusively occupied by schists and slates, dipping to the northwest, while along the eastern and southeastern margin of the area, basalt and quartzporphyry are present. The sedimentary rocks, believed to be of pre-Cambrian age, include sandstones, shales, and a few impure limestones or dolomites which have been invaded by granite intrusions. As a result, the sandstones have been changed into quartzites, the shales into slates, and the limestones or dolomites were altered into a host of minerals that constitute the so-called "skarn rocks". At Ma-On-Shan, where the iron-ore deposits are situated, no dolomite bed occurs, but south of Starling inlet, $8\frac{1}{2}$ miles due north from Ma-On-Shan, a lenticular bed of magnesian limestone or calcareous shale is known to be present. Moreover, in general, the ore-bearing bed of Ma-On-Shan is rich in Magnesia. This can be seen from the following analyses as given in Mr. C. M. Weld's paper on "Notes on an Iron Ore Deposit near Hong Kong, China.": Nos. I and II of this analyses were taken from the richer portions of the ore body, while No. III represents magnetic concentrates from 22 samples of lean ore and skarn. No. IV was an average sample of ore, and No. V was lean ore or rich skarn.

	I	II	III	IV	V.
Fe_2O_3	70.32	65.25	75.36	65.24	38.40
FeO	22.53	22.26	11.37	15.75	15.84
MnO	1.48	.....	0.70	1.03	0.74
SiO_2	1.20	3.99	5.50	6.04	12.70
Al_2O_3		.....	4.46	1.80	1.21
CaO	0.60	......	0.73	0.56	0.40
MgO	3.64	Trace	2.29	11.53	26.24
S	0.110	0.27	0.082	0.09	0.192
P_2O_5	0.009	0.044	Trace	.....	0.028
As	0.008	.....	Nil	.....	0.005
CO_2	.....	.....	Nil	0.80	1.50
Water	.....	7.20	Trace	.....	
Moisture	.....	.....	.....	.....	0.10
Loss	.....	.....	.....	0.16	.....
Total	99.897	99.014	100.492	100.00	97.355
Fe...........	66.75	63.00	61.59	55.82	39.20
P	0.004	0.019	Trace	.....	0.012 .

In examining hand specimens of the skarn, one may often recognize grains of magnetite, quartz, garnet(frequently abundant), pyroxene, amphibole, mica, chlorite, epidote, serpentine, while in thin sections, a mineral that was believed to be periclase was observed to be present in considerable amount. According to Mr. C. M. Weld, the magnetite occurs abundantly distributed throughout the skarn, either in the form of disseminated crystals, or as bodies of variable proportions. From some of the larger bodies, thousands of tons of high-grade iron ore could be mined profitably.

Shan-tung.

Magnetite is known to occur at several places, as, at P'ao-shan, and at King-kwo-shan, while in the vicinity of Che-foo, specular hematite has been found. Iron ore deposits are known in Manchuria, Mongolia and in all the other provinces of China proper that have not been mentioned, but the mode of occurrence, extent, and the mineralogical character of these deposits are not definitely known.

Conclusion.

Judging from the preceding pages, the iron-ore resources of China may seem to be relatively unimportant, but it must be borne in mind that, for the most part, our present knowledge of these resources has been dependent upon information furnished by travellers, missionaries and merchants, and that exceptionally favorable circumstances have made Shan-si* and Hu-peh*1 noted for the richness of their iron-ore deposits. The iron ore of other provinces may be equally important. For instance of the 227 districts *2

* As pointed out in the preceding chapter, southern Shan-si is an elevated dissected plateau and contains an enormous amount of coal that may be easily obtained.

*1 Originally, the Han-yang steel works were projected to be set up in Kwang-tung province. T.T.Read says: "In 1891, while viceroy at Canton, Chang-Chih-tung ordered a steel plant from England. Before the machinery was delivered he had been appointed viceroy at Wu-chang. The plant was accordingly transferred there and set up in a convenient place in the neighbouring town of Han-yang.

*2 These districts are enumerated in a book (in Chinese) on the Mineral Resources of China proper. Unfortunately, no descriptions of the occurrences of the minerals have been given.

(political usage) that have been reported to contain iron ore deposits, only three districts, including Ta-yeh-hien, in which the Ta-yeh Iron Mines are situated, belong to Hu-peh.

More thorough investigation concerning the extent and character of her iron-ore deposits must be made before it can be definitely known as to whether the iron-ore resources of China are as important as her coal resources. The extensive iron resources of China that are at present well known, and her incalculable amounts of limestone, when considered in connection with her enormous coal reserves, will play an extremely important part in the industrial development which is now awakening, as is evidenced by the building of railways, bridges and other public works, and the erection of varied manufacturing establishments.

In the "Mineral Resources of China", iron ores are reported to be present in the following number of districts:-

Province	Number of Districts.
An-kui	5
Che-kiang	8
Chih-li	8
Fu-kien	28
Ho-nan	23
Hu-nan	28
Hu-peh	3
Kan-suh	8
Kiang-si	16
Kiang-su	6
Kwang-tung	11
Kwang-si	6
Kwei-chou	7
Shan-si	25
Shan-tung	13
Shen-si	13
Sze-ch'uan	19.

CHAPTER V11.

THE HUANG-TU FORMATION

In northern China, in the provinces of Kiang-su. An-hwei, Shan-tung, Shan-si, Chih-li, Ho-nan, Shen-si, and Kan-suh, there occurs a peculiar deposit known as the Huang-t'u (yellow earth) formation. This formation, for the most part, forms the Great Plain of Northeastern China, extends into the valleys and to some extent blankets the slopes and even the summits of the adjacent mountains. The altitude at which the Huang-t'u formation is found ranges from a few feet to 8000 feet above sea-level. Its thickness is known to vary from a thin sheet to 2000 feet; but in the Great Plain, the depth to which the thickness may extend has not been determined, probably 1000 feet. The age of the huang-t'u varies from late Pliocene or early Pleistocene to the present. The process of deposition is believed to have been continuous through the Quaternary and is still in progress today.
Some writers use the terms "loess" and "Huangtu formation" interchangeably. Bailey Willis defines the Huangtu formation as including loess and certain stratified sands and gravels, but in some portion of his discussion, he appears to use these terms synonymously. According to the common conception of loess, it is defined as an earth of brownish yellow color. consisting principally of hydrated silicate of alumina with some quartz grains, mica flakes, and calcareous nodules, salts of alkalies or akaline earths and oxides of iron are invariably present. According to Richthofen, it is

characterized by being so soft that it can easily be crushed to pieces with the fingers, and yet so firm that in places where, through erosion, large masses are broken off, it remains standing in perfect vertical walls of several hundred feet in height. Its quartz grains are always angular and its mica flakes instead of being laid down horizontally as if deposited by water are dispersed throughout the mass with every possible orientation. It is further characterized by the homogeneity of its composition; if pure, specimens of loess always contain extremely fine particles of hydarted silicate of alumina, quartz grains, mica flakes, carbonate of lime, alkaline salts, and oxides of iron. The loess is very porous and is traversed by vertical tube-like openings, ramifying downwards like the roots of grass and usually encrusted by carbonate of lime. Richthofen also states that the loess does not exhibit stratification and that the organic remains found therein are chiefly land shells and occasionally bones of various herbivorous and carnivorous mammals, which are identical with or closely allied to those living species that abound on the steppes or grassy plains of to-day. Marine shells have never been discovered in the loess and fresh-water shells are of extremely rare occurrence. Probably these characteristics are common to loess of any locality, China, Central Asia, Central Europe, South America, or Mississippi Valley.

With a full acceptance of the definition of loess by Richthofen, Bailey Willis defines the Huang-t'u formation as that deposit of loess, sand, and gravel, characterized by the predominance of loess as a chief constituent, and by the vertical cleavage peculiar to that variety of clay deposit. According to him, the Huang-t'u formation sometimes is and sometimes is not stratified, and contains nodules of carbonate of lime which frequently occur at definite horizons and are set with the longer axes in a vertical position.

The theories that have been advanced concerning the origin and mode of deposition of the loess are four or five in number. They may be designated as - the marine, the fresh-water, the subterranean, the sub-aerial and the hydro-subaerial theories. The first and at the same time the oldest of these theories was originated by Bennigsen Forder and supported by Kingsmill; but as it is certain that by far the main portion of the loess does not display stratification and since no marine fossils have been found within it, this theory was long ago rejected by geologists. The fresh-water theory was advocated by Lyell, Belt, and Geikie, and according to their hypotheses, in the Ice Age, mud was left behind by glaciers and subsequently sorted, transported and deposited by water. This theory was likewise repudiated, because in the first place the mica flakes as they are found in the loess, do not indicate that they were laid down under water, and in the second place in regions now occupied by glaciers, as for example in Greenland, there is no earth being deposited either directly or indirectly by glaciers that

resembles the loess in composition or texture.
The author of the subterranean theory was H.H.Howorth. According to his idea, Moya or volcanic mud was thrown out in certain volcanic districts, and before it was completely solidified, land animals were drowned in it. Thus he attempted to explain the distribution of the loess in valleys, low-lying lands and even on certain mountain summits, and the presence of the remains of both lower and higher forms of land animals within it. Richthofen maintained that the loess differed completely in composition and structure from all kinds of volcanic muds either ancient or modern. Howorth, however, cited that the Pliocene beds and geyserite* proper of Nebraska were similar in structure and mineralogical composition.

According to Richthofen's subaerial or eolian theory, the prime cause of the genesis of the loess formation was the change of climate of Central and North-eastern Asia--from a mild and moist to an extremely cold and arid condition. As the aridity was so severe that water bodies in these regions were completely evaporated and rivers no longer existed, the heating effect became so intense that the rocks were crumbled, the salts resulting from the evaporation of the water were powdered, and the land surface denuded of vegetation. The pulverized products of rock decomposition, as well as the salts, were then sifted and transported by the winds--the heavier particles being dropped relatively near their source, while the finer ones were carried to longer distances where moisture and vegetation were probably more abundant and topographical conditions favorable for depositions. Thus the loess of Northern China could have been deposited more or less irrespective of altitude and without being stratified. The vertical tubes so abundant and so characteristic in the loess deposits of China were thought by Richthofen to have been caused by the roots of vegetation. Bailey Willis believes that a considerable proportion of the tube-like openings were formed in this manner, but that in part the tubes resulted from the action of descending water upon the included salts.

Believing that the winds alone could not transport such an immense amount of dust from the interior of Asia within a brief geological period and deposit it on the mountains of northern China as well as on the plains, Pumpelly advanced what may be appropriately referred to as the hydro-subaerial theory. He also recognized the wind as an important factor in explaining the origin of the loess, but expressed the belief that fresh water shells had been found in the terrace of Te-hai, and that the texture of the loam in any one basin or in different basins was uniform. In view of these facts he concluded that these basins were originally occupied by lakes, and that into these lakes rivers transported the fine particles of rock waste that were deposited to form the loess. Since the Huang-ho is, and perhaps has always been (?) the only river connecting the

---

Footnote to preceding page:

* The term geyserite is apparently here used as synonym with loess.

interior of Asia with northern China, the sediments must have been brought down by the Yellow river. Pumpelly considered Richthofen's heating effect to be alone inadequate to explain the source of the loess. He believed that much of the material was contributed from the following sources:-

(1) Silt originating from glacial attrition, and

(2) secular disintegration of rocks. Many of the rivers flowing from the mountains into the central region transported large quantities of silts that were produced by glacial attrition of the bed rock and boulder clay. Where the streams decreased in volume, or where the extensive lakes that received them dried up, the fine products of the erosion of a large territory were left to be removed in dust storms. But Pumpelly also writes:- "The second and, I believe, the more important source is in the residuary products of a secular disintegration which we will now consider. In all regions where the soil is protected by a luxuriant vegetation, the greater part of the insoluble products of disintegration remains <u>in situ</u>. Considerable portions of the continents have remained above water during long geological periods. Where this has been the case, and where the region thus exposed enjoyed a peripheral climate with a protecting vegetation and abundant generation of carbonic acid, the felspathic rock have been profoundly affected; granite and gneiss being decomposed often to depths of several hundred feet."

In the elaboration of his theory, Pumpelly did not well explain the deposition of great thicknesses of loess on mountain tops, some of which possess altitudes of 8000 feet above the sea. From his study of the loess areas, Bailey Willis concluded that during the early and middle Tertiary the region had been reduced to a relief of 500 to 1000 feet above sea-level. In the late Pliocene, there followed the Hin-chow age which was characterized by widespread aridity and the degradation of Central Asia. It was at this time that the deposition of the loess commenced. In the succeeding Fon-ho epoch, which covers the Quaternary, crustal deformation expressed itself in mountain building which produced differences in elevation of 7,500 to 10,000 feet or more. Willis writes as follows:- "That active mountain growth by which the Fon-ho epoch is characterized continued to a geologic yesterday; whether it is active or quiescent today, or will be in a geologic tomorrow is indeterminable."

During this period (the Fon-ho stage) valleys and lowlands blanketed by the earlier deposits of loess in the more elevated area has been in large part worked over by winds and to some extent by rain. Mingled with more recent additions that have been brought by the wind from the dry interior parts of Asia, some of the older loess has been covered to low levels, while some of it has been drifted about on adjacent hill slopes. One thus realizes that the Huang-tu has been a "continuously shifting formation" which has also been increasing in volume ever since the late Pliocene.

It is plain that no one theory seems to explain all the underlying factors pertaining to the formation of the loess or huang-t'u of China. A few of the more important points connected with the origin of the loess are summarized as follows: The first cause of the Huang-t'u formation was the change of climate from moist to arid condition which probably occurred during the later Pliocene. In consequence of this, the blanket of vegetation was greatly reduced, and rocks decayed. From time to time the finer products of the disintegration of the rocks were sorted and transported by both winds and water, while the unremovable residues were left in situ to await further weathering. The heavier grains dropped on their way, while the lighter were carried along and deposited to greater distances. The same material may have been repeatedly and alternately removed by wind and water before it reached its final destination--the loess field. During the wet* seasons, rains were the most effective agents in the transportation of the loess, while during the dry seasons the winds were the more important. As the quartz grains in the Huang-t'u formation are generally angular, the material must have been transported more by winds than by water. As at the commencement of the loess epoch, the topography of northern China reached its maturity, large quantities of sediments could have been deposited by the Huang-ho within many of the present valleys, and undoubtedly

* An arid region is not necessarily entirely devoid of rain, as in some parts of northern China, where aridity prevails and dust storms are frequent, crops have been successfully grown each year.

the Great Plain was built up, as it is today, by the fine detritus transported from the interior of Asia through the Yellow river. During the dry seasons, some of the dried-up muds of the alluvial plains were carried from the valleys by the winds and deposited on the slopes and summits of adjacent hills and mountains. Much of this material was probably transported in the form of very fine dust carried along in the upper air currents. As has been described in previous pages, Bailey Willis has shown that one must understand the physiographic history of China since the middle Tertiary in order to fully comprehend the relative values of the factors that have been associated with the accumulation of the Huang-t'u formation. The Huang-t'u formation, in accordance with the definition of Bailey Willis, includes both the loess proper as it is developed in the mountainous regions, where it is characterized by its friability, fineness, and by the presence of small vertical tube-like openings, and where it very rarely displays traces of stratification; and the alluvial Huang-t'u which is confined to the alluvial plains and which frequently displays stratification, occasionally including stratified sands.

As the petrographical character of the Huang-t'u formation of China has already been described, and since its physical aspects are almost universal, descriptions of local deposits are not introduced here, but a few important facts that have not been mentioned may be enumerated:-

The surface of many of the districts underlain by loess possesses a wavy appearance. In the course of its erosion into perpendicular walls, the loess often assumes weird forms, some of which simulate gigantic columns. In some localities vegetation is very poorly developed; in others it is entirely wanting. The relative rapidity with which some of the cliffs develop, is exemplified by the sunken highways that traverse the loess districts. The dust produced by the grinding process of the cart wheels and of the feet of men and beasts is carried away by the winds and the roads thus become sunk below the level of the country.

The loess is in itself a fertile soil, but it seems probable that there are widespread areas within which no irrigation is possible. If some means can be devised whereby these districts may be irrigated, the Huang-t'u formation will prove to be a more universal source of agricultural wealth in China.

CHAPTER VIII.

THE GREAT PLAIN

The Great Plain of northeastern China, which comprises the Huang-ho basin on the north and to some extent the deltaic plain of the Yang-tsze-kiang on the south, covers an area of about 20,000 square miles. Excluding that portion of the Shang-tung peninsula which was formerly probably an island, it stretches from the Yellow Sea and the Gulf of Pe-chi-li on the east to the margin of the elevated plateau of Shan-si and the mountainous region in the province of Ho-nan on the west. From the vicinity of Shang-hai (about lat. 31 degrees north, long. 122 degrees east) in the province of Kiang-su in the south, it extends to the neighbourhood of Peking (about lat. 40 degrees north, long. 117 degrees east) in the province of Chih-li in the north. From north to south the Great Plain is from 700 to 750 miles in length, and from east to west, it varies from 150 to 600 miles in breadth. This extensive area descends gently from an elevation of about 1000 feet on its western margin to sea-level. It is said that its average altitude does not exceed 300 feet above the sea. This vast plain is traversed by numerous smaller rivers and many canals have been constructed through parts of it. In general, the surface of the plain is not diversified by hills or lakes. Locally, however, its southeastern portion is characterized by the presence of many bodies of water and numerous hills. The Great Plain has been built up by the silts and muds brought down by the Huang-ho (2400 miles in length) and the Yang-tsze-kiang (2900 miles in length), and in some measure by the dust transported by the winds. The amount of sediment annually deposited is undoubtedly very large. The very name Huang-ho or Yellow River indicates that an exceptionally large quantity of material is carried in suspension by that river. It has been said that for fifty centuries the water of this river has not once been clear. The growth of the plain has been very rapid. The town of P'u-tai is said to have been situated one Chinese mile west of the sea in the year 200 B.C.,(1 Chinese mile equals .36 English Miles) while in 1730 A.D., this town was about 140 Chinese miles from the coast. Moreover, Sien-shwuy-kow was on the sea in 500 A.D., and it is now 18 Chinese miles inland. Furthermore, it is said that the lower course of the Huang-ho has been shifted more than fifteen times in the last 3000 years. Before 1852, the Yellow River, after flowing eastward through the western part of Ho-nan province, turned at Lung-men-kow in the same province and flowed southeasterly to empty itself into the Yellow Sea at 34 degrees N. But at present, it turns at the same point, flows northeasterly, and discharges its contents into the Gulf of Pe-chi-li at about 38 degrees N. latitude. In the incessant shiftings which have taken place, the river has moved over an area possessing the form of a fan with a magnitude of probably 500 miles from north to south and 300 miles from east to west. There have been five shifts from the Gulf of Pechi-li to the Yellow Sea and back, the river flowing into the former during two periods before the present for a total of 3420 years, and into the latter during two periods for a total of 792 years. The frequency of the change of its channel is undoubtedly due to the damming up of its mouth by the accumulated material brought down by its waters. It has been reported that off the sea-coast the Yellow Sea has been growing shallower every year, although the adjacent land is believed to be rising. The province of Shang-tung is believed to have been at one time a separate island, which has been attached to the main land by the deposition of sediment brought down by the Yellow River.

The amount of material transported and deposited by the waters of any river within any one period depends upon the physical characters and the climate of the surrounding country. As the Huang-ho takes its rise in Tibet and Mongolia and is fed by a multitude of tributaries, which drain regions underlain by the Huang-t'u formation, and since these regions have been denuded of forests, the quantity of material annually transported by the waters of this river is necessarily great, being much greater than the load of the Mississippi river, the Nile, or the Ganges. Dr. George P. Merrill* states that the Huang-ho river annually carries 17, 520,000,000 cubic feet of debris to the ocean.

---

* Merrill Rock Weathering & Soils

It has been estimated, however, that the Huang-ho carries to the sea, each year, 17½ million cubic feet of suspended matter.

The Mississippi river (about 3000 miles long) transports annually 812,500,000,000,000 pounds of silt or a mass which would cover an area of one square mile with a thickness of 241 feet of silt, and in addition, sand and gravel to a thickness of 27 feet. The total quantity of material annually transported would amount to a mass with a base of one square mile and a thickness of 268 feet. The Ganges (1,557 miles in length) annually brings down 6,369,000,000 or 378,100,000 tons of sediment. The Nile (about 3400 miles in length) discharges 150,000,000 tons of sediment each year.

In China disastrous floods have been of frequent occurrence. The earliest recorded* in the ancient annals, occurred in 2297 B.C.. In the 61st year of his reign (2295 B.C.), Emperor Yaou commissioned Kwan, father of Yu, afterward Yu the Great, to control the Great Deluge, but despite nine years labor, he was not successful. In the 72nd year of his reign (of Yaou, 2285 B.C.), Yu undertook the task of his father, and within a period of eight years (in 2277 B.C.) he succeeded in subduing the deluge. This deluge was the greatest that China has ever experienced. The waters lingered in the country for a period of perhaps more than 20 years. The total area affected by this deluge was undoubtedly very great. From his work in dispelling the flood, Yu gained an exact knowledge of the physical conditions or topography of the China of that day. The present Yang-tsze-kiang and its

---

* Kang-keen yih-che luh, Vol. 1, pages 6-7.

tributary Han-kiang, the present Huang-ho with its tributaries the Woi-ho and Lo-ho were pointed out by Yu in the map that was made from his surveys. The devastating flood must have been very intense. It is said that being so enthusiastic and faithful to his work, Yu remained abroad for eight years without visiting his family, although thrice he passed his own door. The following passage translated from the ancient annals portrays the magnitude of his work:- "Shun* commissioned Yu to continue his father's work. In order to drain the nine districts,*1 to open up their channels, to dam their marshes, and to survey their mountains, while travelling on land, he rode in a waggon; on water, he took a boat; in miry regions, he used sledges,*2 and on mountains, he wore hooking sandals." On account of his great achievement, Yu was appointed to succeed Shun as Emperor, and in the 4th year of his reign (2201 B.C.), he cast nine tripods*3 with the gold*4 gathered from the districts. Each of the tripods was adorned by some feature characteristic of each of the nine districts. These may be rightly regarded as the first relief casts made in China. In spite of many elaborate attempts to prevent them, disastrous floods have repeatedly occurred since the famous epoch of flood devastation which has just been described.

---

* Shun was then regent to Emperor Yau, but afterward succeeded him as emperor.

*1 On the completion of his work, Yu divided China into nine "chows" or districts.

*2 A flat-bottomed contrivance used in travelling over miry places.

*3 A large bowl-like vessel having three legs which was used by the ancients for sacrificial purposes.

*4 Here the word "gold" may be synonymous with "metal" - viz, any of the metals.

The leading question in this discussion is: What are the causes of the frequent inundations of the Great Plain in China? The answer may be found in a consideration of the following topics:

(1) Deforestation.

(2) Absence of lakes in those regions that feed the Huang-ho and the Yang-tsze-kiang.

(3) Bad drainage.

(4) Excessive rainfall.

Unquestionably, the chief cause of the floods is to be found in the thorough deforestation of the country. Bad drainage and excess of rainfall are to some extent the direct results of deforestation. It is a recognized fact that a forest, in addition to beautifying the landscape and yielding a wealth of timber products, performs at least three other functions; (1) to retain a large part of the rainfall and regulate the run-off, (2) to minimize erosion, and (3) to prevent rapid evaporation. A forest-clad area, as a general rule, is more porous than a denuded region, because the roots of the trees ramify into the ground, and thus produce numerous openings in which much of the meteoric waters may be retained in large quantity.

The shade afforded by the foliage of a forest greatly reduces the evaporation, and the moist soil beneath the trees often supports a dense growth of shrubs and mosses which may appropriately be likened to a carpet of sponges in that it takes up a large proportion of a rainfall and releases it very gradually to the streams and rivers. Widespread swamps are of frequent occurrences in forested areas, while they are very rare in districts where the forests have been cut down. In brief, forests regulate"the run-off" so that the rivers and streams maintain a more constant flow; deforestation permits rapid run-off, causing great fluctuations in the volumes of rivers and streams.

There are no large lakes at or above the tributaries of the Huang-ho and the Yang-tsze-kiang. This is an important factor,giving rise to the floods that so frequently visit the Huang-ho and the Yang-tsze-kiang valleys, since lakes play the part of great reservoirs from which the run-off is gradually passed to the oceans.

The bad drainage is largely due to the topography of the country. As the Huang-ho and the Yang-tsze-kiang basins descend to the Pacific, first abruptly and then gently, much of the pebbles, sands, and even the muds transported by these rivers, are deposited within the channels of the lower and more gently descending portions of their courses. Because of this fact, artificial embankments are thrown up by the inhabitants in order to confine the waters in the channels, which otherwise are liable to overflow. But during periods of exceptionally heavy rainfall, the torrents are so violent that the embankments, whether natural or artificial, are broken through, and inundation results. In the past, most of the floods occurring in the Huang-ho and in the Yang-tsze valleys were due to these conditions.

Excessive rainfall is another factor leading up to flood devastation. By "excessive rainfall" is meant that within a short period of time - a few days or weeks, or a season, in which the total volume of the rainfall is abnormally great. For instance, at Hokin, the average annual rainfall (the average for eight years) of the Hwai-ho river * within the region noted for the frequency of floods, was 36.67 inches, while in the month of July, 1906, alone, seven inches of rain fell and a great flood was caused; in the same region in August 1910, 11 inches of rain resulted in a very disastrous flood.

The Huang-ho has been known to rise 40 feet in times of flood, and breaking through its embankments to spread over the surrounding country in a devasting current, 30 miles wide and from 10 to 20 feet deep.

How to prevent the flood disasters is a question of the utmost importance for China. There are three ways of prevention - (1) by reforestation, (2) by damming, and (3) by dredging. No one of these means alone can be successful. All three of them must be employed in order to efficiently solve the problem. The forestation of certain districts would eventually produce desirable although not immediate results; the erection of dams would bring immediate results; if dredging is not continuously carried on, the river soon obliterates the work done by the deposition of sands and muds. In addition, new canals must be excavated. In order to bring about immediate, widespread and permanent results, all of these four lines of activity must be carried on

* The Hwai-ho river, 800 miles in length, is situated in Eastern Central China, where it enters the ocean between the Yellow river and the Yang-tsze-kiang.

simultaneously. In seeking a solution of the problem the following scheme seems to commend itself:-

(1) Get the people to cooperate with the Government in the prevention of floods, but before their cooperation can be obtained they must be educated to the realization of the true causes and effects of floods. They must be led to realize that the question of re-forestation is intimately connected with the flood problem as well as with the broader problem of irrigating agricultural lands. To educate the public in this matter, the government and private institutions should give illustrated lectures and send out circulars concerning the matter in question. Moreover, the government should create and enforce laws pertaining to the planting and the cutting down of trees.

(2) Emphasize the beneficial results that would attend the construction of dams and the opening of canals. If the government is unable to undertake the task alone, let charters be granted to corporations for the excavation of desirable canals, as in the case of railroad construction. When this is done, not only will the flood devastation be mitigated, but also traffic will be stimulated.
The construction of dams across the rivers in the upper portions of their courses would tend to regulate the flow of the falls and rapids along the lower portions of the streams. The water power created by the dams as well as the natural water power could then be efficiently utilized. With reasonable encouragement to the investment of capital, numerous

manufacturing industries could be established.

(3) Dredge the lower courses of the Huamg-ho and the Yang-tsze-kiang and the extension of their channels beneath the waters of the Yellow sea. This would bring about two important results:-(1.) It would increase the facility of navigation and(2) it would reduce the sluggishness of the lower courses of these rivers. In addition to being a very real aid in preventing floods, such procedure would expand commerce.

From the remote past to the present, the Great Plain has been a scene of repeated famines because of periods of drought and inundations. The flood of 1906 in the region of the Hwai-ho swept away thousands of homes and terminated many lives. Similar widespread devastation occurred in 1910. In 1887, a single flood of the Huang-ho drowned a million people, besides destroying hundreds of villages and causing famine by which the loss of life was increased. Because of repeated disasters of similar character, the Huang-ho is most appropriately known as "China's Sorrow". If vigorous steps are not quickly taken, a repetition of the floods may be expected in the near future. Nature seems to have been cruel to these people, but, in reality, nature is impartial in its acts, and the people suffer from floods, because the nation has not adapted itself to the conditions. In order to control nature we must first know nature. Here science has its place. Throughout this discussion, the application of the sciences of geology and forestry and the technique of engineering are plainly the important factors that enter into the solution of the problem of the prevention of these floods.