FIG. 1.—Amadeus W. Grabau, First Palaeontologist of the National Geological Survey of China and Professor at Peiping University, a scholar of genius, an enthusiastic teacher and a delightful man.

CHAPTER ONE

THE FIRST SIGNS OF LIFE

IT was a little piece of stone which from the very beginning gave a definite direction to my work in China, and from this beginning my fate unfolded throughout a decade of varied and shifting change, in which the milestones bear the inscriptions: mining expert—fossil collector—archaeologist.

At the beginning of 1914 I had accepted an appointment as adviser to the Chinese Government to arrange a survey of its coalfields and ore resources, and on May 16th I began my work in the Department of Agriculture in Peking.

In the ever-changing foreign colony, with its various elements of diplomats, agents of high finance, technical experts, missionaries and adventurers, I made the acquaintance of a Danish mining engineer of the name of F. C. Mathiesen, who earned his living by doing all sorts of odd jobs, principally the investigation of coal seams and galena deposits for Chinese speculators. One day Mathiesen invited me home, and it was there that I was to see what was to prove my lucky star. On his table lay a piece of hematite ore. It was unlike anything I had ever seen before, but it resembled most the curious kind of ore which is known in English as " Kidney ore ". On examining it more closely I found that it was composed of pear-shaped bodies, consisting of thin laminae of red iron oxide, and between these large pear-shaped bodies the interstices were filled with small grains of ore, as large as linseed, and also composed of layer upon layer of iron oxide. It was a kind of hematite ore entirely new to science, and it looked rich. If there existed much of this beautiful and curious ore, it should prove a very valuable asset.

Mathiesen did not seem to know very much about this piece of ore. He had got it from his boy, whose home was in a small mountain village some tens of miles to the north of Peking. The boy declared that there was plenty of this remarkable red stone in the hills around the village where his parents lived.

This sounded extremely tempting, and I immediately began to ponder what I should do in order, very quietly, to set things moving. I could not go there without asking permission of my Chinese superiors, and I did not want to do so until I knew something certain about the ore, which might be quite valueless.

It fortunately happened that the Swedish Diamond Drill Boring Company had sent out with me a very clever and skilful man, a drilling foreman, C. F. Erikson, who knew everything between heaven and earth, from the art of finding water in solid rock to the wonderful method of reading human character from the bumps and dents of crania. I knew that, in addition to his other accomplishments, Erikson was very good at essaying ore discoveries, and I therefore proposed to Mathiesen that he and Erikson should go with the Chinese boy to the hills and examine the wonderful hematite ore *in situ*.

It turned out to be a very fortunate expedition. When Erikson returned, he reported that the beautiful red ore was a regular layer lying between sandstone, shale and limestone, and that it could be traced from hill to hill for a distance of several miles.

It was evident that we had discovered ore resources of at least one or two million tons.

I then went to the Director of the Mines Department, Mr. Chang Yi Ou, a pleasant and amiable little mining engineer, who had received his technical training in Belgium. Mine was a delicate errand, for just as I desired to find an opportunity to

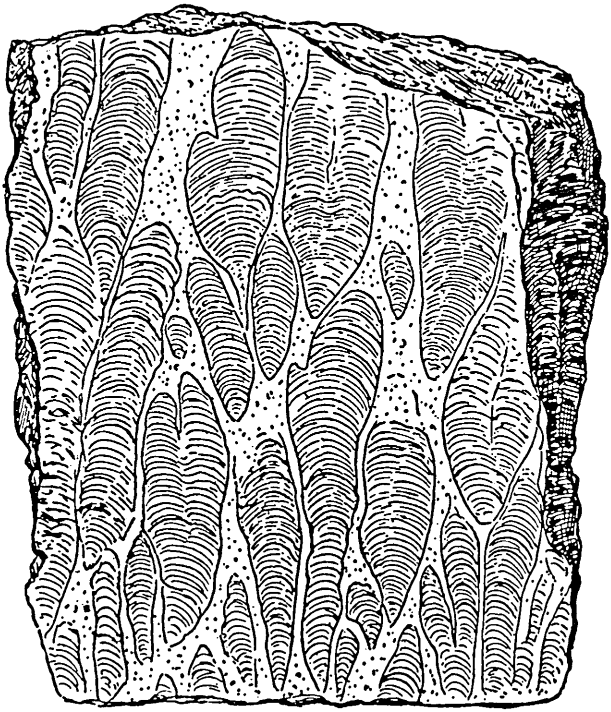


FIG. 2.—Stromatolitic ore. Hsin Yao.

examine this ore on behalf of the Chinese Government, so also it was my duty to protect as far as possible Mr. Mathiesen, on whose desk I had found the piece of stone which gave rise to the whole investigation.

"Mr. Chang", I said, "a foreigner, whose name I cannot disclose, has shown me some ore specimens which I believe to be of great interest. I cannot even tell you what kind of ore it is, nor where it is to be found. If you have confidence in me, you must first promise to give this foreigner 500 dollars if, after examination, I find that the ore is good."

He sought to draw me, but I appealed once again to his confidence.

" Very well ", said Mr. Chang, " I accept your proposal without asking you for any details."

I then placed before him the specimens of ore which Erikson had brought back. Chang's kindly eyes beamed with delight when he heard what was at stake. Half an hour later he had submitted the matter to His Excellency the Minister of Agriculture, and it was resolved that we should immediately institute an official investigation of the ore-field at Hsin Yao. A few days later I, Mathiesen and Erikson were *en route*, together with porters, for the hills, and at the end of October I was able to report to the Minister that there were in the Hsin Yao hills at least 17 million tons of fine hematite ore conveniently situated for mining.

But this was not all. We had reason to suppose that the ore-field was much more extensive than our investigation had shown. Our distinguished countryman, Dr. E. T. Nyström, now took over the work, and on November 18th he discovered very large new ore deposits at P'ang Chia Pu, about 12 miles south-west of Hsin Yao. Here the quantities of available ore probably amount to about 50 million tons, and in certain parts of the field the seam of ore shows a thickness of 3 metres. These new discoveries of iron-ore were left untouched during the following years, but towards the end of the Great War, when prices of ore had risen to the skies, it was proposed to exploit the ore in the Hsüan-Lung field, as I have named this district.

In the spring of 1918 a company was formed for mining in the great P'ang Chia Pu field, but difficulties were immediately encountered in the organization of the transport of the ore from the rugged hill districts where the thick and rich beds of ore break the surface of the ground. At the beginning of May I was ordered by the Chinese Government to assist the new company with a report on this transport problem, and for this purpose I departed for Hsüan Hua Fu, a fairly large town on the Peking-Kalgan railway, from which it was proposed to construct a branch line to P'ang Chia Pu.

I had, however, my own little secret plan for the solution of the ore problem. As early as 1914 I had observed certain geological conditions which seemed to indicate that the ore-bearing formations extend westward from P'ang Chia Pu in the direction of the railway, and I therefore conceived the possibility of finding ore in the Hsüan Hua Fu district. My eagerness to set out in search of ore was increased by the fact that just at that time I had bought from my countryman F. A. Larson a large and magnificent horse, which had come all the way from remote Ili in Central Asia, and I was full of impatience to see how this splendid animal would acquit itself in the hilly district north-east of Hsüan Hua Fu.

But in point of fact nothing very much came of my riding tour on that occasion, for I succeeded beyond all expectation in the rapidity of my search for iron-ore deposits. I had scarcely proceeded more than a few miles beyond the northern town-gate of Hsüan Hua Fu before I found in the river bed the first pieces of ore, and some hours later I found a fine complete section through the new ore-field, which I named Yen Tung Shan after one of the hills.

This unexpected discovery of workable iron ore quite near to the railway aroused no little attention in Government circles in Peking, and I received out in the field a present from the Minister of Agriculture which I have preserved as a most treasured souvenir of an interesting and eventful period of my work. Most amusing, however, was the survey and sampling of the new ore, which work I conducted during the early summer, when the mountain flora at 800 metres altitude was first flowering.

My idyllic quarters in an old water-mill, the rides to and from work, the mountain slopes with their wealth of flowers, the warm and beautiful weather, and the sense of doing productive work—all these make a singularly beautiful memory of this period.

My new discoveries at Hsüan Hua Fu agitated the minds of Peking. Two very high officials vied with each other to obtain concessions to mine this new ore, situated so conveniently near the Peking-Kalgan railway that a branch line of only a few miles length was all that was required to begin shipments of an ore which could be mined on the surface. In a short time the

Lung-Yen Company was formed to exploit the ore, and during the autumn of 1918 40,000 tons of ore were sent 1,250 kilometres to Hanyang on the Yangtse River, where large-scale smelting experiments were made with very great success. In November, however, came the armistice, accompanied by a rapid fall of prices in the ore market. Mining at Yen Tung Shan was discontinued and has never been resumed since, owing to the political disturbances in China.

The iron deposits of Yen Tung Shan occur in strata, just like coal seams. The mountain strata are only slightly inclined, and it is therefore possible to trace the ore as a connected band in the mountain cliffs for stretches of miles (Plate 1). Indeed, owing to the stratified formation of the ore it was possible for me and my collaborators to trace the seams, with some interruptions, over a distance of 82 kilometres and to show that one

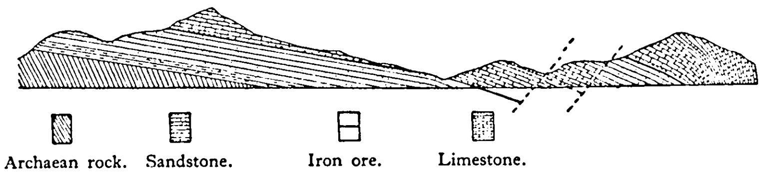


FIG. 3.—Section through Yen Tung Shan.

of the largest iron ore deposits of the world had once existed in this area, even though movements of the earth-crust, combined with destructive geological forces, have left only some tens of millions of tons of ore available for mining.

The Hsüan-Lung ore is loose and easily crumbles in the fingers to a red powder. For the greater part it is oolitic, i.e. it consists of grains of the size of linseed, which on examination prove to be composed of thin laminae, one beneath the other, in much the same way as an onion is built up.

There is, however, another type of ore, which constitutes whole seams at P'ang Chia Pu, and this ore shows a structure which places it in a class apart and without parallel in any other part of the world. It was a piece of this curious ore which I had seen on Mr. Mathiesen's desk and which had been the cause of the discovery of the Hsüan-Lung ores.

This type of ore has been called " Kidney ore ", but this designation is very unsatisfactory, and another term, *stromatolitic ore*, somewhat difficult for laymen, has gained recognition among experts.

Stromatolitic ore (Fig. 2, p. 3) consists to a large extent of pear-shaped bodies, which appear very clearly in a vertical section through the ore seam. These pear-shaped structures are at most 5 cm. long and 1–2 cm. broad. The pears are always vertical in the seam, with the tips downward, and the tips themselves consist of a large oolitic grain, made up of layer upon layer of the red iron oxide. The pear also reveals the same structure of thin layers of iron oxide, which are all domed on top, and it is evident that the stromatolite or pear, as we shall for convenience sake call these bodies, has been formed by the further growth of the oolitic grain, which, when it reached a certain dimension, became so heavy that it could no longer be lifted by the iron depositing forces and therefore grew only in an upward direction.

In this description I have purposely used the expression " grew up " in order to indicate that the " pears " are probably *fossil remains* of a primitive vegetable or animal form, or that in any event some kind of organism contributed to the development of these characteristic bodies. If this interpretation be correct, than with the discovery of the Hsüan-Lung ores we also discovered the earliest traces of organisms in the Chinese mountain strata.

The ore seams in the Hsüan-Lung field (Fig. 3, p. 6) are embedded in sandstone and shale, and above this formation rests a limestone formation several hundred metres thick. Whilst surveying at Yen Tung Shan in the summer of 1918, I observed in this limestone some lumpy formations, with a high percentage of silica, of some centimetres section and consisting of concentric layers, which gave the whole the appearance of a large onion.

In the same vast limestone formations, which are very extensive in Northern China, I made numerous discoveries of these onion-shaped bodies in another district, and this under circumstances which deserve to be told.

In the middle of September 1920, after I had returned from a summer journey in Mongolia, I received in my home in Peking an interesting and welcome visit from two young fellow-countrymen. They were the engineer Gösta Richert, the son of the famous hydraulic engineer Professor Richert, and his young wife.

The Richerts were on a holiday tour after a period of duty in Shanghai. In their Chinese programme was also included a journey to the Yangtse River through the famous gorges which, together with the canyon of the Colorado River, belong to the most magnificent phenomena of erosion in the world.

These young Swedes, however, had too little time before their return to Sweden to undertake this very prolonged journey. It was under these circumstances that I proposed that I should be their guide to a canyon which, though it certainly could not compare with a journey through the Yangtse gorges, yet offered instead the excitement that it was uncertain whether any white man had yet made at one stretch the dangerous and difficult tour which I now proposed. Since the canyon which I proposed to visit was quite near Peking and since my programme would, according to circumstances, be either a success or a failure in a maximum period of ten days, Mr. and Mrs. Richert accepted my proposal.

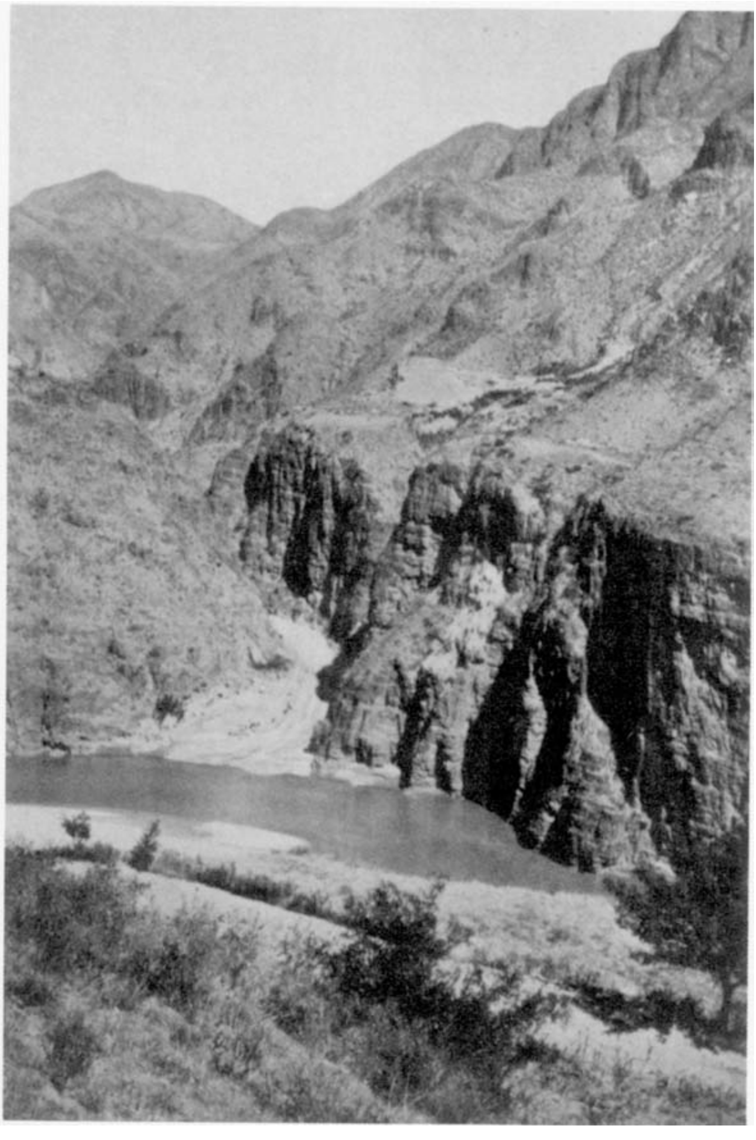
In order that the reader may understand what was in my mind when I proposed this plan, it is necessary for me briefly to describe the topographical conditions north and west of Peking.

Whereas the ancient Chinese capital looks out to the east and south over an absolutely flat alluvial plain, which slopes down invisibly to the ocean, it is surrounded to the north and west by sharply broken mountainous regions with peaks rising to over 1,500 metres. Through these mountains run many rivers, which have cut deep and narrow canyons through the mountain strata, and especially through the vast limestone formations. The most important of these rivers is the Hun River, or Hun Ho, to use the Chinese name.

The course of the Hun Ho north-west of Peking is very peculiar. It flows across the 500-metre-high Huailai plateau, but turns south against the barrier of limestone mountains and breaks through them in a narrow, wild canyon gorge, several hundred metres in depth.

The lower part of the Hun Ho canyon is easily accessible, and I have, together with some Chinese geologists, made a detailed map of this part of the river. Regarding the upper part of the

PLATE 2



The Collenia-bearing limestone in the gorge of the Hun river

[face page 8

canyon, on the other hand, information was scarce, though it pointed to extreme inaccessibility. It was said that one could penetrate some distance into the canyon from the Huailai plateau, but that subsequently there were only steep, inaccessible mountain walls, which nobody had ever been known to pass.

This was the tempting project which the Richerts and I soon agreed to attempt together. The risk was slight, for nothing worse could happen to us than the humiliation of having to turn back.

On September 20th we departed from Peking by train for Huailai station, which was the starting point of our excursion. Two days later we entered the section of the Hun Ho valley, which is one of the most curious and exceptional of erosion valleys. Characteristic of such valleys is the curious and apparently abnormal circumstance that from a relatively low plain the river forces a way, in the form of a deep gorge, right through the mountain masses which obstruct its course. The explanation of the origin of these valleys is that they are very ancient, so ancient that the whole of the topography of the district has changed, whilst the river obstinately sticks to its old bed, and slowly, inch by inch, cuts its way through the mountain chain in proportion as the latter rises in its course. Owing to this curious origin these valleys are often very deep, steep and inaccessible.

For two days we wandered through a part of the canyon in which there were scarcely any human dwellings and where scarcely a path could be seen, so that we were obliged to scramble forward as best we could along the steep canyon walls, holding on to bushes and tree-roots.

We spent the night in a lonely cottage. Around us we had only the cliffs, several hundred metres in height, which rose up steeply and in fantastic forms above us. Below us the rushing river raced in numerous small rapids (Plate 2). In many places the precipices pushed out in perpendicular buttresses, so that we had to cross to the other side and were frequently compelled to wade the river. Fortunately we always found a fordable place and were thus able to keep our small equipment dry and in good condition.

It was during this adventurous excursion to the Hun canyon that I found that certain strata in the several hundred metres thick limestone are full of the silicious, onion-like bodies which I had first observed on the slopes of Yen Tung Shan.

As early as 1918, when I first discovered the concentric structures in the limestone strata above the Hsüan Lung ore, I knew that similar structures had been found in mountain strata of approximately the same age in America and Europe, which in those countries had been described as remains of prehistoric coral-like animals or calcareous algae, under the generic name of *Gymnosolen*, *Cryptozoon* and *Collenia*. It thus seemed probable that in these onion-like bodies in the silicious limestone of Northern China, as also in the pear-shaped stromatolites of the hematite ore, we have to do with the earliest traces of organic life in this part of the world.

When the famous American geologist and palaeontologist A. W. Grabau came to Peking in 1920 as a teacher of his sciences at the Peking University and as a palaeontologist to the Geological Survey of China, he applied himself to an investigation of these ancient formations. To the material collected by me in the Hun Ho canyon was added other material collected by Grabau and his pupils in the Nankou pass north of Peking, and on the basis of this material Grabau described the three forms, *Collenia sinensis*, *C. cylindrica* and *C. angulata*.

We have already indicated that *Collenia* and *Cryptozoon*, etc., are very differently regarded by different writers. Some consider them akin to certain coral-like animals (*stromatopores*); others, such as Grabau, regard them as calcareous algae.[1] Holtedahl does not consider them real fossils but rather structures arising from the precipitation of lime by algae or bacteria. But even on this interpretation they yet remain what we called them in the title of this chapter, *the earliest traces of life* in Northern China.

The great German traveller, Ferd. von Richthofen, who by his expeditions during the 'sixties and 'seventies laid the foundations of our knowledge of the geology of China, differentiated

[1] Grabau, "The Sinian System", *Bulletin of the Geological Society of China*, Vol. I, 1922.
Grabau, *Stratigraphy of China*, Peking, 1923–4.

in his monumental work *China, 1877–1885*, a series of formations of old stratified rocks to which he gave the name " Sinian system ", thereby designating its rôle as a fundamental element in the rock structure of China.

Since then, it is true, it has been shown that Richthofen also included in this Sinian formation younger strata, which we now call Cambrian, but Grabau in his work, *The Sinian System*, published in 1922, has suggested that the term " Sinian " should be restricted to the pre-Cambrian formations, which other writers have called neo-Proterozoic, Algonkian, etc. He further considers that this term should be introduced as a term applying to the whole earth, similar to the names of later formations, such as Cambrian, Silurian, etc.

Thus in Northern China the Sinian system consists of a quartzite sandstone overlaid with shale containing iron-ore seams. Above them there is a thick silicious limestone with Collenia-like formations, such as we have already encountered in the Hsüan-Lung field in the Hun canyon.

A very well-known and significant development of the Sinian system is to be found in the north-western states of North America in the so-called " Belt " district, where, in a series of more than 10,000 metres thickness, are to be found not only *Collenia* but also remains of a Crustacean of the Eurypterus type, *Beltia danai*.

In Europe the Sinian series is represented by the Torredonian sandstone in Scotland, the red Jotnian sandstones of Fennoscandia, and the stromatolitic dolomites in northern Norway.

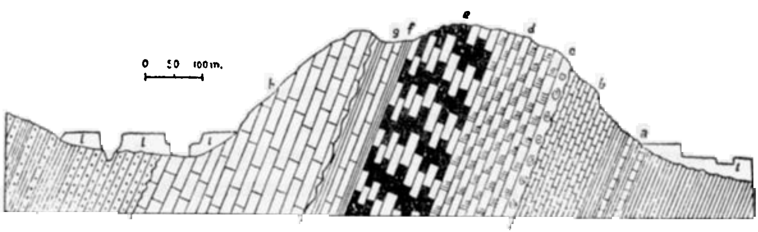
All these primeval mountain strata in different parts of the world are characterized by the fact that fossils (with the exception of the doubtful *Collenia*) are entirely absent or very rare, as in the Belt formation of North America.

In this respect the Sinian formations are in sharp and inexplicable contrast with the next succeeding formation, the Cambrian, in which limestones and shales are often covered with fossil impressions, thus indicating an already highly developed and varied animal life.

We shall now examine some of these Cambrian and later fossil-bearing strata of Northern China.

When Ferd. von Richthofen, during one of his long expeditions in China, travelled along the shores of the Yellow Sea from Manchuria to the province of Chihli, he came to a rich coalfield at Kaiping, which first became better known to science by his account of it. In his day the coal was mined only by old-fashioned Chinese methods in small and irregular pits. When a modern company, the Kailan Mining Administration, under Anglo-Belgian direction, acquired control of this rich coalfield, the mining was completely rationalized and concentrated in a few large mines at Tongshan, Machiakou, Chaokochuang and Linshi, situated along the edge of the great trough-like structure in which the coal formation is enfolded.

In the late summer of 1914, a few months after my arrival in Peking, I had an opportunity of visiting the Kaiping basin and



Carboniferous system. Ordovician. Cambrian.

FIG. 4.—Section through the series of strata at the northern edge of the Kaiping coalfield (*By Sun and Grabau.*)

was able in an essential point—the age of the so-called Carboniferous limestone—to correct Richthofen's view of the geology of the district.

In the spring of 1916 I was sent by the Ministry of Agriculture to Kaiping to conduct final practical tests with students of the school of geology, which was training young men for appointments to the Geological Survey of China. I then spent ten days in this district with my twenty-two students, and we explored the whole of the coal basin in various directions.

After Dr. Grabau had taken the direction of palaeontological studies in China into his strong and expert hands, he instituted a more thorough investigation of the series of strata and fossils of the Kaiping area. The data which are given below are for the most part derived from his work, *The Stratigraphy of China*, Part I, 1923–4.

The mountain-forming forces, of which we shall have more to say in a succeeding chapter, have here compressed the originally horizontal strata, so that they now form a trough-like structure which the geologists call a synclinal fold. Towards the sea, in a southerly direction, the rock strata sink down under the later strata, which here cover the whole of the bed-rock, and form a low-lying plain as far as the Yellow Sea in the south.

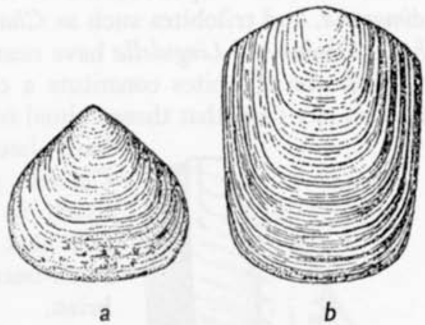


FIG. 5.—Cambrian brachiopods. *a, Obolus luanhsiensis* Grabau ; *b, Lingulella dimorpha* Sun. (Three times magnified.)

North of the coal basin itself, on the other hand, we find an undulating landscape consisting of silicious limestone. In this district we did not find any of the formations which we described under the name of *Collenia* and found north of Peking, but it is probable that further research will show that they exist here too. In any case it is quite certain, judging by the character of the rock formation, that we are dealing here with the same Sinian formation as yielded us the fossil formations in the Peking district.

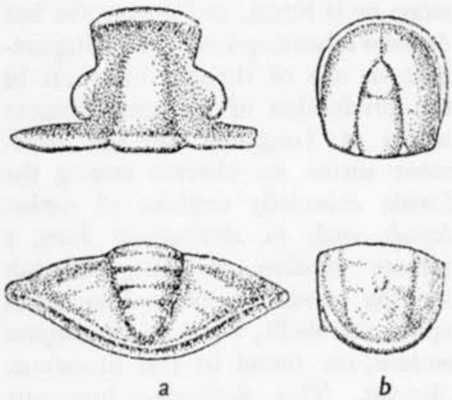


FIG. 6.—Cambrian trilobites. *a, Changshania conica* Sun ; *b, Agnostus hoi* Sun. (7 times magnified.)

Upon the Sinian limestone rests a thick and varying series of later rock strata. The lower ones are shown more in detail in Fig. 4, which is taken from the above-mentioned work of Grabau. Immediately above the Sinian formation follows a series of shales in different colours, and shale-like thinly laminated limestone. In these strata, which are known throughout the world as *Cambrian*, we find in large quantities the first absolutely indisputable fossils, brachiopods such as *Obolus luanhsiensis* and *Lingulella dimorpha*, and trilobites such as *Changshania conica* and *Agnostus hoi*. *Obolus and Lingulella* have near relations in the seas to-day, whereas the trilobites constitute a class long extinct. It is certain, in any case, that these animal forms, and many others which have been described by the young Chinese palaeontologist, Y. C. Sun, lived in a shallow marine area and that they belong to the oldest fossil-bearing formation, the Cambrian.

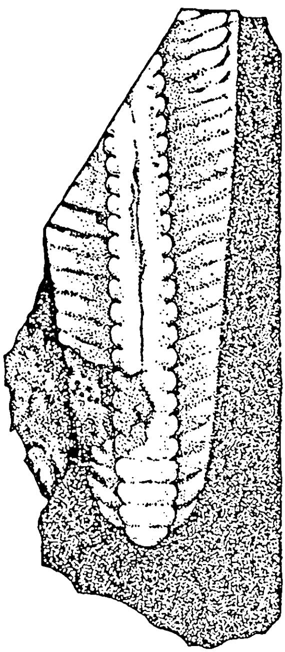


FIG. 7.—Ordovician cuttle-fish. *Actinoceras tani* Grabau. (Natural size.)

Above the Cambrian series there is a limestone formation some hundred metres thick. This limestone is of great practical importance. Especially in Tongshan, in the western part of the Kaiping field, it is quarried on a large scale and is hewn for building stone or is burnt, and during the last decades it has acquired further importance as one of the raw materials in the production of the great cement works at Tongshan. In this limestone series we observe among the fossils especially sections of *cephalopods*, such as *Actinoceras Tani*, a remote relation of the cuttle-fish of the modern seas. Also small spiral sea-shells, such as *Lophospira morrisi* and *Pagodispira dorothea*, are found in this limestone, which is again a marine deposit. This *Actinoceras* limestone belongs to the geological system which is commonly called *Ordovician*.

The Ordovician *Actinoceras* limestone is covered in turn by a stratum, 85 metres thick, of shale and sandstone, probably deposited in rivers and lakes, but there follows a marine stratum, a limestone rich in corals and brachiopods, such as *Lithostrotion*