T H E   G E O L O G Y   O F   C H I N A

BY

J. S. L E E.

(With a Geological Map, a Physiographic and Tectonic Map, An Economic Map, and 62 Geological Sections).

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TO

PROFESSOR W. S. BOULTON

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P R E F A C E

In the year 1917 I took the opportunity during my Summer holiday to prepare a route-map of China, showing the geology of some parts of that country, which I hoped might serve a useful purpose in my future geological research. On the completion of this map, which perhaps hardly deserves the name geological map, because of its necessarily disconnected character, I was pleased to show it to Prof. W. S. Boulton. After a cursory glance Prof. Boulton remarked that it would be a useful undertaking if I could carry my preliminary enquiry a stage further. At once I realized the pressing need of such a work, and decided to seek for more information.

As the same professor has happily pointed out, the nature of my task is to briefly but comprehensively summarise the work that has been done in connection with Chinese geology during the past; thus to indicate the state of our knowledge at present; and further, to bring out the vital points which demand investigation in the immediate future. Being the first, as far as I am aware, to attempt a work of this nature, I am encouraged to make a strenuous effort.

Further consideration of the vast ground covered by the subject, and the limited time at my disposal, has compelled me however, to confine myself to the most important region of the whole Republic, viz the eighteen provinces, usually known as China Proper; and to reserve the description and discussion of the geology of Manchuria, Mongolia, Chinese Turkestan and Tibet to some future occasion, after I have accomplished my intended journey. At the present time, in these regions outside China Proper not only is there very little geological information available, but the geographical data are often uncertain or even misleading. Mountains, rivers, lakes etc., of considerable importance, indicated on one map are often absent or marked under different names on another. Therefore it is necessary to establish our geographical knowledge with regard to the said regions, preferably by making a reliable topographical map, before we can start systematic geological study.

At the end of this work (In a separate copy) a bibliography of geological literature with mining notes concerning China Proper, as well as its dependencies is introduced. It is by no means complete, but I have little doubt that the more important works and papers are mentioned.

J. S. L.

The University of Birmingham, May, 1918.

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I N T R O D U C T I O N.

Students of Chinese literature can hardly fail to find the occasional occurrence of a prominient phrase "Blue seas change into mulberry fields". The same phrase may be used as a type-expression for a peculiar form of pessimism alluding to the inconstancy of human affairs, or may be referred to for depicting and emphasizing the mighty and persistent changes taking place in the universe. It is the latter sense of its use that demands our attention. In one of the Chinese writings of antiquity, indeed the oldest still surviving to-day believed to be compiled and revised by four great thinkers the expression "intense heat hidden in the earth" was used allegorically in the revelation of some philosophical doctrine.

A close enquiry into the meaning of such phrases and their original source would show that the grander geological processes and the more important physical conditions existing inside the earth had not entirely escaped the notice of the ancient philosophers. Thus the first of these quotations may be reasonably understood to indicate the integration of the almost imperceptible but incessant changes of the earth's surface during a long period of time, on these facts modern uniformitarianism is partially based; while the latter clearly involves some conception of a state of our planet, which suggests the existence of highly heated magma or "potential liquid" with its necessary temperature gradient towards the outer portion of the cold crust.

Similar brief statements and rude suggestions shaping the more definite conclusions borne under modern elaborate scientific studies are not infrequently met with among ancient Chinese literature. The Chinese literati either gaze at these mythical words with indifferent regard or adapt them for the purpose of decorating their scholastic writings. One quotes after another until the saying gradually become proverbial truths. But apart from a large number of volumes treating of drainage systems and a few volumes treating of minerals, Chinese literature, as far as the writers knowledge goes, is singularly wanting in original systematic contributions to geological science.

The rapid growth of science in general during the last few decades has not spared its influence in pressing geologists to contribute their due share. The hunger for wider knowledge naturally aroused by the fascinating restoration of ancient landscape, and the vivid speculation of physiography through the succeeding periods of the earth's history, together with growing need for opening up and developing the natural stores of mineral wealth have led many western geologists to direct their attention to a new hunting ground in the Far East. The little knowledge that we have at present concerning the geology of that vast area in the Asiatic continent embraced by the Chinese Republic is largely due to the efforts of those enthusiastic investigators who felt the call of the time. It may not be too early for us to-day to appeal to the rising generation of the "Middle Kingdom" to realize their responsibility in helping towards the advancement of pure science on the one hand, and on the other the solution of many vital problems directly or indirectly related to industry through the light of the knowledge so obtained. For the science of geology nature has prepared "tongues in the leaves of ANCIENT trees and books in the BURIED brooks". It is only needed on our part to cultivate such aspiration and capability as to listen and to read.

Before the exploration of Pumpelly during the years I862 -I865 the only records of geological observations in China were stray or occasional notes made by travellers and missionaries to relieve the monotony of their journeys. Credit should be attributed to this pioneer who made the first adventure under enormous difficulty for the ~~sole~~ purpose of scientific research. His route covered a large part of eastern Asia. The results of his work were published by the Smithsonian ~~Society~~ Institution under the title "Geological research in China, Japan & Mongolia".

Kingsmill during his long stay in China, made occasional visits to a number of localities in the southern provinces and contributed a series of papers of which the "Notes on the geology of China" and "A sketch of the Geology of a portion of Quangtung" appear to be most important. In the year I867 a "Sketch of a journey from Canton to Hankow through the provinc of Kwangtung, Kwangsi, Hunan, with geological notes", was published in Journ. N. China Br. Roy. Asiatic Soc. by Bickmore who also described the "Recent geological changes in China & Japan" in 1868. At about the same time, A. David recorded his observations in Journ. d'un voyage en Mongolie et d'un voyage en Chine dan le Kiang-si". Before these publications had attracted the attention of geologists to any extent the famous explorer Von Richthofen had already commenced his penetrating journey. After publishing a large number of orig--inal papers, Richthofen and those who carried out his last will summed up his observations and far reaching conclusions in the important work "China" together with an atlas of geol--ogical maps. These maps although in places the inferences drawn seem scarcely justified by the field-observations, (as will appear later)are not only unique and therefore valuable; but they have, no doubt, stimulated, and will con--tinue to stimulate the interest of all investigators of the geological structure of China.

Since Richthofen's time the number of explorers showed a decided tendency to increase, the cause of which may be traced to the romantic reports made by the earlier workers.

Loczy, an early contempory of Richthofen n, attached him-self to the expedition of Szechenyi during the years 1877-1880. They entered into China from the lower Yang-tze valley and proceeded N. W. ward along the valley of the River Han. After crossing the Tsingling-Shan and making observations in the foothills of the Nan-Shan, the expedition directed its journey southward towards the mountain regions of western Su-Chuan and Yun-nan. Notwithstanding the dangerous nature of the route, and the unfavorable circumstances for geological observations, Loczy was able, during his journey, to compile voluminous reports, many of which are valuable contributions to science, and they still stand as an authoritative source of information inasmuch as they remain our only source of information for those regions.

Obrutchov a few years later made several traverses across south Mongolia, south Kan-su and a part of Shensi. Among his brilliant records of observations one may count those which were made during his exploration into the high mountain ranges of Nan-Shan in N.W. China. Unfortunately the work that has been done by Obrutchov, in N. and N.W. China has been published, largely if not exclusively, in the form of field notes; the deduction of systematic geological data from these notes is an exceedingly difficult matter. The writer has carefully searched for a separate volume of his work in which he promised to give a full account of his deduction based on his own views; but has not so far met with success. In all probability the said work has never been published.

In the year 1897 E. E. Anert wrote two papers on the geological results obtained by Koslow and Roborowsky during their journey in central Asia and Manchuria. They were published under the titles "Vorlauf Bericht der Mandschur'schen Expedition. d. k. russ. geog. Gesell. Geol. Theil". (Isw. russ. geogr.

Geo., vol. I3) and Expedition zur Erforschung der Mandschurie. Geol. Theil". (z.d. Georg. Geo., St. Petersburg.)

K. Futterer in the year I898 entered into China from the northwestern frontier of the country. The first part of his journey was devoted to Chinese Turkestan. Travelling southeastward he crossed the great desert of Gobi, and made observations along the northwestern and southern flanks of the Nan-shan ranges, particularly in those regions surrounding the lake Ku-ku-nor and near the head waters of the Hwang-ho. Thence southeastward he crossed the Tsing-ling-shan, and finally arrived at the middle Yang-tze valley. There he completed his journey in the year I899. The observations made by K. Futterer are recorded in his work "Durch Asien".

During the same years (I898-I899) F. Leprince-Ringuet was instructed by the French ministry of foriegn affairs to join the expedition sent to China by the Credit Lyonnais. After travelling through Chi-li, Shan-si, Ho-nan and Hupeh, Leprince-Ringuet reported his observations and summarized his views in an able paper "Etude geologique sur la Nord de la Chine". (Ann. des mines 9 serie vol. I4 I90I) In the same paper he also made reference to Richthofen's work in N. China and modified some of the latter's conclusions.

More or less as contemporaries of the authors mentioned above, we may count Lorenz who has made valuable contributions to the stratigraphy of Shan-tung, Vogelsang whose journey in W. Hupeh and N. Chi-li has brought many facts of petrological and economic importance to light, Abendanon who devoted his study on the structure and stratigraphy of the Red basin of Su-chuan and the Yang-tze gorges. The papers and maps published by these writers are referred to and discussed to some extent later.

In the years 1903-1904 an expedition headed by Bailey Willis under the auspices of the Carnegei Institution, started from Pekin and journeyed round N. China, and ended at the Yang-tze gorges. Their route, apparently was never far from one of the routes taken by Richthofen. Dr. Willis summarized the observations obtained by his own party and compared their view with those held by Richthofen, Suess, Loczy and others in his comprehensive and able work, the "Systematic geology of China". This work would have been more complete and authoritative if the auther had been able to obtain further data from southern China in addition to his own observations in northern China.

Our geological knowledge concerning the southwestern provinces of China is largely due to the labour of French explorers. In the years 1897-1899 A. Leclere, a French mining engineer, approached China from her S.W. frontier and penetrated into Yun-nan, Kwei-chou and Kwang-si. He observed the occurrence of Cambrian, Devonian, Carboniferous and Triassic formations. The fossils collected by him were studied by M. Douville and others who also recognized the Rheatic and Liassic forms. The rock specimens were studied by MM. Levy, Locroix and Leclere himself. The full report of the research was presented to the Academie des Sciences in the year 1900. Leclere was followed by G. H. M. Monod who discovered the Devonian coal in Kwei-chou, and made observations at many localities in S. E. Yun-nan. A comprehensive account about Legendre's journey in the Lo-lo district is also given by him. Among the papers published by G. H. Monod the following two appear to be most important: "Contribution a l'etude geologique des provinces meridionales de la Chine". Bul econom. Indo-Chine, vol 4 pp. 619-637 1901, "Notes sur quelques points en litige au sujet des formations de la Chine meridionale et du Tonkin". -Marseille. (Imp. Huard.)

Later H. Lantenois published an interesting account of his research under the title "Note sur la geologie et mines de la region comprise entre Lao-kay et Yun-nan-fu" with a map. The fossils collected by Lantenois were described by Mansuy and others. (Ann. des Mines 1907.) In the years 1910-1911 J. Deprat contributed a series of papers to the Academie des Sciences. (Serie de Compt-Rendus donnes a l'Academie des Sciences) The same author in the following years, (1912-1913) with the co-operation of the able palaeotologist Mansuy, published an elaborate memoir entitled "Etude geologique du Yun-nan Orientale" The writer has not met any other work dealing with the geology of China, which attains the equal precision and lucidity as the said volumes.

About the geology of Liau-tung, Yang-tze provinces and to some extent Shan-tung, different Japanese writers have written a number of papers in the course of the last fifteen years. Yokoyama, Yabe, Inouye, Sakahaya and Noda are among the well-known contributors. Their papers are principally published in the Journ. Soc. Imp. College. Japan, Journ. Geol. Soc. Tokyo and the Bulletin of the Imp. Geol. Survey of Japan.

Recently, Mr. V. K. Ting and Mr. C. Y. Wang, the only two Chinese geologists known to the writer, have contributed a few papers having an important bearing on economic geology. It is to be regretted that the results of the reported research of Mr. Ting in the provinces of Yun-nan and Shan-si and of Mr. Wang in the provinces of Kwang-si and Hu-nan have not been published.

Shortly before the Chinese Revolution in 1911, the Chinese government has established a geological survey under the Ministry of Agriculture and Commerce. The same establishment is still existing under the directorship of Mr. V. K. Ting. Whether the Chinese government is willing to raise sufficient funds and to spend them in an efficient way to carry out an extensive survey is a matter that remains to be seen. So far, the writer has not found any reports or memoirs published by the Chinese geological Survey.

Other intermittent and sporadic information relating to Chinese geology has appeared in reports, journals, and magazines, and has grown in quantity largely in consequence of the recent development of mining activities through-out the country.

Thus it is necessary at the outset to gather up the multitude of scattered papers and reports, and extract from them the reliable geological data. In this way such information can take its proper place in geological literature; and further, the lines for future investigations can be mapped out.

I am fully conscious of the danger in trying to extract the truth from so much material which cannot be taken for granted as all reliable; yet by advancing with caution and appealing always to well-established first principles of geology, I am emboldened to brave the dangers and push forward.

This thesis is divided into three sections. In section I physiography is treated only in brevity in order to save space and time. In section II general geology is dealt with at some length in four chapters. The first three are principally intended to record the classified facts with a certain amount of discussion, involving, to some extent, the writer's own opinion; while the fourth represents the complete general conclusion of the writer. Matters relating to economic geology are mentioned in section III to which a plate is attached, showing the mineral deposits in China.

With the regard to the choice of information, the writer realizes the importance, at the present stage, of laying stress on securing what he judges to be the more important and reliable facts; premature arguments which sometimes amount to mere surmise, are not introduced wherever avoidable.

CHAPTER I. GENERAL PHYSIOGRAPHICAL DESCRIPTION OF CHINA PROPER.

A cursory glance at a geographical map of China would direct our attention to the significant array of three mighty rivers - Hwang-ho, Yang-tze-kiang and Si-kiang, flowing in a general direction from west to east. The last-named, Si-kiang or the West River, though it covers a much smaller distance than the other two, is nevertheless, equally important from physiographical point of view. The fact that all these rivers flow from west to east in a general sense, at once suggests that the highland of China Proper lies on the west, which gradually diminishes in height towards east, till finially it sinks beneath the Yellow Sea. Such a broad statement is only true in a very broad sense. Mountain ranges that attain conspicuous height, and play important parts in determining the topographical features of the whole country are met both in N. E. and S. E. China, as will be described later. For a moment let us consider how these three rivers have divided the whole country, or looking from another point of view, how they are separated from one another.

Northern China.

The northernmost one of the three rivers mentioned above, is Hwang-ho or the Yellow River. As it emerges from the mountainous region of Nan-shan, the river describes a large bend, shaping an inverted U, and embraces Ordos in the north, a part of Kan-su and the whole of Shan-si in the south. To the north of this bend lies the southern border of the Mongolian plateau To the N.W. of it stands the plateau-like upland of the Ala-shan mantled by Gobi sands. The region enveloped by the bend is nearly rectangular. In all probability, it is on account of the presence of this huge block that the winding course of Hwang-ho has been determined. In the absence of a proper name, the writer proposes a term Shen-kan plateau to indicate the area almost encircled by the large bend of the Hwang-ho.

To the east of the Shen-kan plateau, and separated from it by the eastern limb of the great bend of the Hwang-ho, we find, a long watershed trending NNE. To the east of this watershed lies the valley of Fen-ho which is continued to the NNE. by the plain of Tai-yuan. Further east there appears the Shan-si plateau which stands conspicuously and abruptly above the plain of Ho-nan on the south, and the alluvial plain on the east.

The narrow constriction of the Hwang-ho valley in the south of Shan-si and north of Ho-nan widens into two open plains, each of them extends hundreds of miles: the one opening toward N.E. in the shape of a funnel, lies between northwestern Shan-tung and southeastern Chi-li. The surface of this plain is monotonously flat and is often flooded by the thrilling overflow of the Yellow River. We may call it the plain of S.E. Chi

-li as it occupies a large area of that part of the province . The other lies to the east due south of the constriction of the Hwang-ho valley. It is likewise an alluvial plain covering large areas of northern Ho-nan, northern An-hwei, and northern Kiang-su. Since the year I852 the lower course of Hwang-ho has deserted this plain and adopted its present course in the plain of S. E. Chi-li. The writer proposes to call this plain Kwan-bei plain from the ancient name of the province of An-hwei. Between this plain and the plain of S. E. Chi-li protrudes bold-ly the upland of Shan-tung. The latter is best described as an island rising above the alluvial sea.

Bordering the northwestern margin of the plain of S. E. Chi-li, there arise parallel mountain ranges running in a NE-SW direction. They have been so expressively described by Richthofen as the "Grill of Peking".[78] These parallel ranges occ-upy a large tract of northwestern Chi-li. Proceeding north-eastward they meet the southern prolongation of the Great Khingan range; and to the S.W., they join the Wu-tai and the Ki-chou-shan mountains which end on their S.W. side, at the border of the plain of Tai-yuan, locally known as the Hin-chou basin. The southern extention of the Wu-tai mountains completely amalga-mates with the Shan-si plateau already referred to .Between the headland, so to speak, of the Shan-si plateau and the Grill of Peking, after the fashion of an embayment, lies a portion of the vast plain of S.E. Chi-li. To the southeast of the embayment the isle of Shan-tung with its rugged weather-eaten feature, stands boldly in the distance. It is because of this peculiar configuration that we recognize the grand and unique scenery of N.E. China.

Returning to the head waters of the Hwang-ho, and to the north of it, we find a series of parallel mountain ranges entering China Proper from the N.W. At first they pursue a S.E. course, then turn towards E.S.E. then E., and finally sweep round in a N.E. direction. Along the foot of the last-mentioned portion, the upper Hwang-ho flows northeastward. These high mountain ranges form a transitional belt between the Tibetan plateau, the central water shed of eastern and central Asia, and the Gobi region of southern Mongolia. The northwestern part of these arcuate ranges are collectively known as Nan-shan ranges.

Central China

Separating the valley of the Hwang-ho in northern China from the valley of the Yang-tze in central China, the mighty range of the Tsing-ling runs in an equatorial direction for more than 800 miles. This range may be regarded as the main central water shed of China Proper. Unlike the eastern prolongation of the Nan-shan ranges which bends towards N.E., the Tsing-ling range is believed by Richthofen and others to be the direct rectilinear continuation of the Kwen-lun range in central Asia, and

(Morphological axis)

shows no conspicuous bending of its orographic axis as it proceeds eastwards. Entering into China Proper by the northern border of the Tibetan plateau, (to the south of the town of Didao) the Tsing-ling range always pursues a course E. by S.. After passing through southern Kan-su, southern Shen-si, southern Ho-nan, it terminates somewhat abruptly at the head water of the river Hwai. Along its length several branches are given off; among them Ta-pa-shan and Mu-ling are most important. The first of the two forms the northern border of the province of Su-chuan, and runs towards E.S.E. into central Hupeh. The second branch forms the divide between the province of Ho-nan and the province of Hupeh, and runs in a direction approximately parallel to the Ta-pa-shan branch. This range separates the waters feeding the river Han and Yang-tze-kiang on its southern side, from the head waters of the river Whai on its northern side.

To the south of the Tsing-ling range, in the province of Su-chuan, two neighbouring physiographiaal regions are distinguished by their striking contrast of seenic peculiarities:

(a) The western region forms the transitional area between the Tibetan plateau and China Proper with parallel high mountain ranges running N-S. Between Ta-tsien-lu and Ba-tung, the Gambu attains a height of 7,400m, and the peaks of Deava are believed to be still higher. The upper Yang-tze-kiang or King-sha-kiang flows across these parallel mountains in a sinuous course. The same ranges extend southwards into W. Yun-nan. This feature is well represented on any geographical map of China by the parallel lines indicating the Kin-sha-kiang - gold-sand-river, the Ya-lung-kiang, the river Me-kong, and the river Salween and their tributaries. Regarding western Su-chuan and western Yunnan as a single physiographical unit, the writer proposes the name Si-shiu ranges for indicating the whole mountainous area. This region is comparable with the Nan-shan ranges in as far a it forms the steps by which the central upland of eastern Asia descends to China. (b) A vast plain or basin lies immediately to the east of the Si-shiu mountainous region. The country within this basin is comparatively low and generally flat. By far the greatest part of its surface is covered by red, fertile soil. Hence it has been called the red basin of Su-chuan. Although the surface feature is nowhere characterized by prominent relief, parallel hill ranges running, in general, in a northeasterly direction are noticeable. Sometimes they are round and gentle in outline, and sometimes they are flat-topped or even characterized by a depressed crest. On the north, the basin is bordered by Ta-pa-shan, the important branch of the Tsing-ling range; on the south it reaches the border of Yun-nan and penetrates into N.W. Kwei-chou. On the east three long and deep gorges appear, through which the Yang-tze flows eastwards.

To the east of the gorge district mentioned above, and on both sides of the Yang-tze, the surface features are somewhat irregular: Isolated hills sometimes arrange themselves in the shape of a dissected chain, or at other times swell up from the low land at random. Broadly speaking, we recognize an ill-defined and irregular basin limited on the east by the hilly region of S.E. Hupeh, on the south by the hills bordering the southern margin of the lake Tung-ting in Hu-nan. We may call it the middle Yang-tze basin or the Tung-ting basin.

To the S.E. of the hilly regions of southeastern Hupeh lies the lake of Po-yang. From the neighbourhood of this lake to the southeast and the east beyond Nan-king, the whole region is characterized by the array of hills and mountains having a dominant northeasterly trend. Following the change of the trend of orographic axes the river Yang-tze bends suddenly towards N.E. This northeasterly trend is so conspicuous and prevails in so extensive an area in the lower Yang-tze valley that it enables us to recognize a physiographical region covering the area of Kiang-si, southern An-hwei, and southwestern Kiang-su. We may conveniently call it the Ning-gang region after the ancient names of Kiang-si and Nan-king.

Southern China.

Let us now follow the main watershed of southern China from the west to the east. This watershed divides the valley of Si-kiang from the valley of upper and middle Yang-tze. We have already seen that the Si-shiu ranges extend from western Su-chuan into western and central Yun-nan. The strong relief of the latter districts caused by the parallel mountain ranges, and deep intermontane valleys, is gradually replaced eastward by broad prolongation of plateau-like highland. Towards the province of Kwei-chou, the land surface is charactized by the feature of a true plateau which reaches as far as western Hu-nan. Geographers have already given it a name Kwei-chou plateau.

On the southern border of the Kwei-chou plateau, between Kwang-si and Kwei-chou a conspicuous range begins to appear which runs in an easterly direction, forming the divide between Hu-nan and Kwang-tung. Further east, it reaches the head waters of Gang-kiang in the southern part of the province of Kiang-si. Thence east-ward a complete change of orographic axis takes place. This W-by S - E by N mighty range is known as the Nan-ling or South-range, which answers to the Tsing-ling range further north. The area to the north of the crest line of the Nan-ling range is drained into the Yang-tze, while that to the south of it is, on the western part drained into the Si-kiang, and on the eastern part directly into China Sea. The whole area embraced by the province of Kwang-si and a large part of western Kwang-tung, being drained by the river Si-kiang, may be regarded as Si-kiang valley.

In Yun-nan the orographic features are somewhat peculiar. The chains bifurcate into two branches: Those lying in the west have a N-S trend, while those in the east trend S.S.E. The latter runs parallel to the Red and Black rivers with decreasing height towards Tonkin. Between these bifurcated chains lies the open plain of Pu-er. According to Suess[187] the bifurcation probably occurs at a place somewhere between Ta-li-fu and Yung-tsang-fu. It is due to this eastern branch of the bifurcated chain that the river Kin-sha-kiang is suddenly forced to take an easterly course along the northern border of Yun-nan; and that the tributaries of Kin-sha-kiang are separated from those feeding the Red river and Black rivers.

Southeastern China.

Having made a broad survey of the regions adjoining the three river valleys, there only remains the coastal provinces of southeastern China - Che-kiang and Fu-kien, to be dealt with. We have already seen, as we proceeded from the W. to the E. of central China, that the change of orographic axis in the neighbourhood of the Po-yang lake is followed by the alteration of the course of the Yang-tze from S.E. to N.E. Again the Nan-ling range which runs almost W-E, suddenly gives way to an entirely different system of mountains at the head waters of Gang-kiang. These changes, as we would naturally expect, foreshadow the approach of a set of different physiographical features characterizing the southeastern provinces.

Starting from the northeastern corner of Kwang-tung, a mountain range of considerable height runs towards N.N.E., and forms the northwestern border of Fu-kien and Che-kiang. The hills of Hang-chou appear to be the northeastern end of the same range. The southern part of this range is generally known as Ta-yu-ling. Towards the north, the range is less persistent and less continuous; various local names such as Pao-er-shan, Wu-lung-shan etc. have been given to it. For convenience, the writer proposes to call the whole range Ta-yu-ling. The area lying to the S.E. of the Ta-yu-ling is drained by rivers running in the directions predominantly perpendicular to the axis of the range, but occasionally parallel to it. e.g., The river Tung-kiang or East River, runs in its upper half perpendicular and in its lower half parallel to the N.N.E. trend of the watershed. The river Kiu-lung-kiang which enters into the Formosa Strait at Chang-chou, flows almost strictly in a direction perpendicular to the axis of the Ta-yu-ling. The course of the river Min-kiang follows the trend of the same range for its upper half—a smaller half; but at the south of the town of Yen-ping, it bends abruptly, and describes an angle of nearly 90 degrees. Thence southeastward, an E.S.E. course is persistently persued by the river, until it enters into the Formosa Strait. Similar E.S.E. course is observed with the Wu-kiang which enters into the Yellow Sea at Wen-chou. The only large river in this

CHAPTER II

DESCRIPTION OF THE SEVERAL PHYSIOGRAPHICAL REGIONS

Only those physiographical features which appear to bear close relation to tectonics or otherwise important are dealt with in further detail.

The eastern and southeastern border of the Mongolian plateau.

(a) The eastern boundary of the Mongolian plateau is marked by the Great Khingan range trending N.N.E.-S.S.W. Rising from the southern side of the river Argun at about latitude 55°N. longtitude 124°E., the range extends persistently towards S.S.W., until it meets the parallel hill ranges in N.W. Chi-li at about latitude 42°N. longtitude 115°E. This range is peculiar inasmuch as it only possesses an eastern slope, representing, as it were, the landing at the head of the staircase. By this gigantic step Mongolia descends to Manchuria.

In the eastern Gobi region, from Urga to Kalgan, the country is not a desert plain, as it is generally believed to be , but is more or less occupied by hills of fairly high altitude varying from 1400m to 1500m. The hills diminish in height towards of Ku-ku-kho-to.[138] More or less continuous with the ranges mentioned above but trending in a more westerly direction, are lofty and precipitous heights; along their feet the Hwang-ho flows eastwards. The western part of these mountains is called Muni-ula by Prjewalski and Wula-shan by Rockhill.[135] It reaches an altitude of 8000ft and forms a sharply defined block which terminates on the northern side of the Hwang-ho in a wild manner.

About 50K.M. west of Shara-chata rises the Suma-chata range; the latter is higher than the former, but runs in a parallel direction. To the north of the In-shan range and more or less parallel to it, there arises a series of mountains Ou-than-djo, Tshanyim-ula, Shok-hcin-daban, Sheiten-ulaetc., separated by intermontane plains. Further north lies the vast area covered by the Gobi sands.

Curving with the N.W. bend of the Hwang-ho, is the arcuate range of Chara-narin-ula or Black-Mountain. It extends 370K.M.. Between this range and the present course of the Hwanh-ho lies an Alluvial plain traversed by a number of abandoned courses of the same river. The eastern portion of the range trends W.S.W. which bends westward to a S.S.W. trend. The whole range is deeply incised. Ravines and canons run in a direction oblique to its orographic axis.

N.W. of Chara-narin-ula, and parallel to it, Obrutchov encountered parallel mountain ranges which diminish in height towards the Gobi-Altai. According to Suess, the S.W. continuati of the Chara-narin-ula is far more extensive than it is generally believed to be. His inference is drawn from the account furnished by Karsuakow[34] and Koslow.[37a] These two explorers met two heights — the Barguste-ula and its probable southwestern prolongation the Gori-Yavari. These mountains are steep and precipitous suggesting some relationship to the principal chain,[140] the Chara-narin-ula. They extend across the desert with a northeasterly trend and vanish at a place about 80 miles N.E. of the town of Kan-su.

The western limb of the large bend of the Hwang-ho is bordered on the western side by the Ala-shan range rising to an altitude of 3000m in the vicinity of Ning-sha-fu. The western flank of this mountain is covered by desert sands. It is believed by Obrutchov that the mountain ranges coming from the N.W. meet underneath the sands of the Ala-shan. Loczy also thinks that the ranges bordering the Hwang-ho stand in some relation to the eastern termination of the Nan-shan ranges. Suess after a close examination of the data relating to the surface features of the eastern Nan-shan, was compelled to accept the view held by Loczy and Obrutchov. It seems to be a significant fact that the arc thus formed by the union of the two ranges shows a rude parallelism to the amphitheatre of Irktsuk.

The Shen-kan plateau

This region is customarily divided by Chinese geographers into two parts: (I) The northern, sparsely populated region of

Ordos is separated by the Great Wall from (2) the southern, more thickly populated region of Shen-si and Kan-su. The southern limit of this plateau is defined by the river Wei which flows in an easterly direction, and joins the Hwang-ho in the neighbourhood of Tung-kwan.

The main watershed of the Shen-kan plateau runs obliquely across the huge rectangular block defined by the Hwang-ho and the Wei-ho. It trends N.E., and partially coincides with the eastern portion of the Great Wall. The area lying to the N.W. of the main watershed is drained into the western limb of the great bend of the Hwang-ho; and that lying to the S.E. of it is drained, on the northern part into the eastern limb of the great bend of the Hwang-ho, and on the southern part into the Wei-ho.

By far the greatest part of this region is covered by wind-borne deposits. The atmosphere is extremely dry. Only that ~~these~~ kind of vegetation which require least amount of moisture can maintain their life. The general climatic conditions often become aeolian during a period of drought.

The Nan-shan ranges

The northeastern forerunner of the Nan-shan ranges is the Lung-shan range which lies to the N.E. of Su-chou and Gan-chou, and runs in a S.E. direction, i.e., parallel to the other ranges to be described presently. These mountains are divisible into three portions along their length: Each of them possesses certain morphological peculiarities: Imagining ourselves approaching the ranges from the N.E. and making three traverses, we should come across each member in the order described below.

(a) N.W. Nan-shan. To the south of the head waters of the western tributaries of the Su-lei-shui, (such as the Si-shui etc.) and the streams which unite at the town of Schi-bao-chien, there arises the Da-ssjue-shan range or the Great-Snow-mountain. To the south of the Da-ssjue-shan lies the Ye-ma-shan. Between the Da-ssjue-shan and the Ye-ma-shan, the river Ye-ma-shui flows westward. This river is often dry. To the S.W. of the Ye-ma-shan stands the Humboldt range which is separated, on the N.E., from the Ye-ma-shan, by the valley of the Dsurgyn-gol; on the S.W., from the Ritter range by the valley of the Chaltyn-gol. Further S.W. lies the Muschketow mountain which appears to be, on Obrutchov's map, the western continuation of the south Kuku-nor range in the central Nan-shan region.

(b) Central Nan-shan. According to Obrutchov, the region of central Nan-shan is bounded on the northeastern side by a conspicuous range called the Richthofen mountain or the Chi-lien-shan,. The N.E. flank of this mountain is cut by a number of parallel consequent streams flowing northeastward. Among the rivers, the Lin-shui and the Da-pei-shui, are the longest. The town of Su-chou lies between the lower courses of these two rivers. While travelling in the central Richthofen range, from the Zsiu-fo-she to the Da-she valley, Obrutchov observed a thick moraine at an altitude of 3410m. Peaks rising above 4600m to 4800m were also seen by the same geologist. Apparently glacial conditions prevail in those localities at the present time. The next range to the S.W. of the Richthofen mountain is the To-lai-shan. Although the latter is less imposing and smaller in size than the former, it is likewise covered by eternal snow. Between the To-lai-shan and the Richthofen mountain lies the valley of the Chun-shui, and a tributary of the Da-pei-shui. To the S.W. of the To-lai-shan runs the Alexander III range which probably rises to 6000m. It is separated from the To-lai-shan by the valley of the To-lai-chuan, i.e., the upper course of the Da-pei-shui. To the S.W. of the Alexander III range lies the Su-le-nan-shan or the Suess mountain of Obrutchov. Between this mountain and the Alexander III range the Su-lei-shui flows northward. Further S.W. the mountain ranges flatten out into the open swamp of South Tsaidam.

(c) S.W. Nan-shan. Between Lian-chou and Lan-chou the snow-clad Nan-shan ranges suffer a remarkable bend, giving rise to parallel arcuate heights with their concave side opening towards the north.[67] The northernmost member of these approximately concentric arcs is the Mo-mo-shan which is believed by Obrutchov to be the southeastern prolongation of the Richthofen range. It runs at first in an E.S.E. direction, but near the eastern end of the Shi-tsho-tse-shan the general trend becomes E.N.E. Thence eastward it is continued by the Da-tao-bei-shan. The next arc following on the south of the Mo-mo-shan and its eastern contination is the Shi-shan which appears to be the continuation of the To-lai-shan and the Ma-ling-shan in the centra

Nan-shan region. Eastward the Shi-shan arc is continued by the Ping-fan-shan of Obrutchov. Along the southwestern side of the Ma-ling-shan, the river Ta-tung-ho flows southeastwards, and joins the upper Hwang-ho at a place west of Lan-chou. To the S.W. of the Ta-tung-ho valley and the north of the lake Ku-ku-nor the mountain ranges are somewaht irregular, showing a tendency to converge towards N.W. and to diverge towards S.E. The town of Si-ning lies in the open fork. To the S.W. of the lake Ku-ku-nor, long parallel ranges again appear. The first one bordering the lake is the south Ku-ku-nor range; this range is separated from its southwestern successor, the Semeno mountain by the open desert valley of Da-ban-sun-gobi and a number of lakes.

The Shan-si plateaus

The province of Shan-si is naturally divided into three portions —— the eastern true plateau, the central plain or valley, and the western plateau-like upland. The central plain occupies the least area. These strips of land extend in a meridional direction.

(a) The characteristic features of the eastern plateau is best appreciated by imagining ourselves making a traverse from its southeastern border to the northwest. To the north of Hwai-king-fu, Ho-nan, the vast plain of S.E. Chi-li and northern Ho-nan suddenly ends at the abrupt, wall-like edge of the Shan-si plateau which rises to a height of 2000ft above the plain or 3000ft above the sea. Its rugged castellated top is one of the most striking features. About I20lis northwest of this edge, a second rise of similar character lifts the surface of the ground still higher. Above the second rise the altitude is believed to be 6000ft above the sea level. The simple feature of the plateau sometimes betrays the advanced phase of erosion, which is particularly noticeable in the neighbourhood of the famous mining district Yang-cheng-hsien. N.W. to the Wu-ling pass (5000ft) the ground again falls abruptly, forming the western edge of the eastern plateau. In the gorges cut by streams consequent to this striking change of altitude, a large number of coal mines are seen in the districts of I-chung-hsien, Fou-shan-hsien etc.

(b) The central plain or the Fen-ho valley is bordered on both sides by mountain ranges of varying height. The eastern boundary of the valley runs along the western slopes of the Ho-shan and its southern continuation, the Fong-huang-shan range. The slope of this broken range, i.e. the western edge of the eastern Shan-si plateau is generally steep and precipitous. The trend of the range curves with the course of the Fen-ho; The Ho-shan range trends almost N-S, but the Fong-huang-shan range trends N.N.E. on its northern part, and S.W. on its southern part. Thus the eastern margin of the Fen-ho valley, or the western edge of the eastern Shan-si plateau describes an arc with its concave side facing N.W. Further southwest, this arc is continued by the Ta-hwa-shan range which curves from E.N.E. to W. by S. Finally the range amalgamates with the mighty Tsing-ling.

The western boundary of the Fen-ho valley is sometimes marked by a gentle rise or sometimes by an abrupt change of ground. The mountains lying to the west of Wen-shui-hsien and their southern continuation, the O-shan range (= Ngo-Shan), are among the more conspicuous heights which border the western margin of the Fen-ho valley. The front of these heights is as a whole, less precipetous and less sharp than that of the corresponding ranges bordering the eastern margin of the valley.

(c) With regard to the peculiar surface features of the western upland of Shan-si, the writer is unable to find any information.

The upland of Shan-tung

The upland of Shan-tung is bounded on the S.W. by the Grand Canal, and on the N.W. by the western portion of the Kiao-chi railway —— from Chi-nan-fu to Wei-hsien. The whole region is divided by a depressed area in the middle of the province, lying between Kiao-chou and Wei-hsien. In this lowland the Wei-ho, the Kiao-ho and their tributaries flow from the S. to the N., and enter into the Gulf of Chi-li. To the east of the central depression lies the rugged and precipitous peninsula ; to the west of it mountain ranges rise to great altitudes.

(a) In western Shan-tung three series of parallel high mountain ranges are recognizable; each of them possesses a peculiar orographic axis. (I) To the west of the Yi-ho which flows from the north to the south, and joins the Grand Canal at the south of Pei-chou, four conspicuous parallel ranges appear. The southeastern parts of these ranges trend N.W.-S.E. But, proceeding northwestward, their axes change from S.E.-N.W. to E.-W. If we draw a line by joining the points where the bending of the axes take place, we would find such a line running almost perpendicular to the N.W. trend, that is, it runs in a northeasterly direction. Enumerating the ranges from the S.W. to the N.E., the first is the Chuan-ku-shan which lies to the N.E. of Tsou-hsien, Teng-hsien, Yi-hsien, and throws off a large number of parallel consequent streams from its southwestern flank to feed the Grand Canal. The second is the Meng-shan (4500ft.) which lies to the N.E. of Ssui-shui-hsien and Pei-hsien. In the valley between the first and the second range, two longitudinal streams flow in opposite direction. The one that runs towards the N.W. - the Tzu-ho, bends southward at Yen-chou-fu, and joins the Grand Canal; the other which runs towards the S.E. - the Fang-ho, joins the Yi-ho at Yi-chou-fu. The third range is the Lien-hwa-shan (3280ft.) which lies to the N.E. of Hsiu-tai-hsien and Meng-yin-hsien, and is separated from the second range, Meng-shan, by the valley of the Wen-ho and the Tung-wen-ho. These two rivers flow in opposite directions, and join the Grand Canal and the Yi-ho respectively in the exactly similar manner as the Tzu-ho and the Fang-ho do. The fourth is the Yung-fu-shan or the Ao-shan which lies to the N.E. of the head waters of the Yi-ho and the Wu-wen-ho, a tributary of the Wen-ho. This fourth range is the shortest among the four, but it is most conspicuous in its way of changing the trend. (2) To the north and N.E. of these parallel mountains we find another series of ranges which trend more or less E.N.E. The Ti-shan and the Tai-shan (5050ft. at summit) ranges between Chi-nan-fu and Tai-an-fu, the Ta-ku-shan and the Ta-hsien ranges between Chin-chou-fu and the head waters of the Yun-ho are the typical examples of this series. (3) A third series running almost N.-S are particularly noticeable in the region to the east of the Yi-ho and the Shiu-ho. The latter flows southward as far as Shu-yung-hsien, thence sweeps round toward the east and finally enters into the Yellow Sea.

(b) Although the topographical features of eastern Shan-tung is not so regular as those of western Shan-tung, a water-shed with its surface crest line trending E.N.-S.W. is recognizable in the N.W. part of the peninsula. It extends from the S.W. of Lai-chou-fu, and passes the vicinity of Chao-yuen-hsien. Further N.E. in the south part of Hwang-hsien, the trend change from S.W.-N.E. to W.-E. At a point to the north of Chao-yuen-hsien the watershed attains an altitude of 2500ft. Its average height increases eastward. At the summit of the Ai-shan, the eastern terminal of the watershed, a height of 3100ft. is recorded. A large number of small consequent streams drain the coastal districts lying to the N.W. of this watershed, into the Gulf of Chi-li. Parallel to the southern coast of the peninsula, between Lai-yang-hsien and Hai-yang-hsien, another watershed exists. It assumes the similar trend as that in the northwestern part of the peninsula, but rises to a smaller altitude on the average. (from I300ft.to 2000ft.) Between these two watersheds lies a highly eroded central area with dissected chains approximately trending N.-S. In the valleys between the chains the river Wu-lung-ho, Ta-ku-ho and their tributaries flow southwards into the Yellow Sea.[197]

The Red basin of Su-chuan

It has been already stated that the basin is bordered on the north by imposing mountain ranges. From western Ta-pa-shan to Niu-tu-shan the axes of the bordering mountains curve from almost E.-W. to N.E.-S.W. From Niu-tu-shan southward the trend of the heights bends from N.E.-S.W. to N.N.E.-S.S.W. The altitude of these arcuate ranges diminishes for a time towards the north of Ya-chou; but to the S.W. of the same town conspicuous parallel ranges again appear, trending N.-S. They are collectively known as the Ta-shan-ling, or the Great-mountain-range. Suess compares these mountains bordering the northwestern margin of the red basin with the Chara-narin-ula range in south Mongolia.[141] On the southeast, the basin is bordered by a long continuous scarp —the edge of the Kwei-chow plateau; on the south its margin apparently extends as far as the south of Yun-ning.

In the eastern part of the basin, more or less parallel hill ranges rise to a height varying from 300m to 400m above the plain. The mean altitude of these hills gradually diminishes towards the northern and the western part of the basin; and they show a tendency of approaching one another towards the northeastern part of the basin, as if they were laterally compressed. Between Chung-king and Lung-chang there are five rows of such hills trending N. E. From Chung-king to Ta-tsu four rows of flat topped ridges are reported to occur. As these ridges extend northward, the definition of each ridge gradually becomes vague. To the southeast of Ho-chou where the Kia-ling-kiang comes from the north, the five different hill ranges completely amalgamate into a united whole. Here the river cuts gorges along its winding path producing attractive scenery. Further northeast, at a place to the north of the town of Wan-hsien, hillocks rising to a height of about 400m, run in a E.N.E. direction. To the north of Ta-ning their trend is completely in accordance with the eastern prolongation of the Ta-pa-shan range. viz, E. S. E. It is significant that the change of the trend of these hills is almost strictly followed by the corresponding change of the course of the river Yang-tze in the eastern part of the basin.

In the southern and western part of the basin there are only two characteristic long ridges: One runs in a northeasterly direction, and passes the neighbourhood of Sui-fu; and the other runs towards Ya-chou. Both of them disappear towards the northeast. Between Lung-chang and Kia-ting there is a large number of low hills, but none of them seem to possess the peculiar feature of the ridges described above.

In the northwestern part of the basin lies a rectangular plain. On the northeastern border of this plain is situated the town of Chen-tu, hence this plain is generally called the plain of Chen-tu. Bordering the east and northeast of the Chen-tu plain, are fairly notable hill ranges which on the east trend almost N.-S., while on the N.E. trend N.N.W.

In the northern and central part of the basin, the ground is essentially flat. Nowhere it exhibits significant relief except on the border of the basin. To the north of Kwang-yuang-hsien Richthofen observed parallel mountain ranges attaining an altitude of 2000ft, trending W.20°S.[79] Since they are outside the basin, they should be regarded as members of the Ta-pa-shan range.

The river Yang-tze enters into the Red Basin from its southwestern corner and travels in a northeasterly direction. At Sui-fu it receives the water of the Min-kiang from the N.W. After cutting across the ridge near Sui-fu, (described above) it still advances in a general northeasterly direction, but describes a rather sinuous course. In the neighbourhood of Chung-king it again cuts across a number of ridges and receive the water of the Kia-lin-kiang from the north near the town of Chung-king. At Fou-chow the river Wu-kiang meets the Yang-tze from the south. Thence northeastward it follows the trend of the ridges, viz. N.N.E., for a considerable distance.

To the south of Wan-hsien the river bends towards the east, completely in accordance with the trend of the hill ranges which also bend toward the east as they approach the lofty Ta-pa-shan range, the important branch of the Tsing-ling-shan. Thence the Yangtze cuts a straight channel till the gorge district is reached.

The Kwei-chou plateau

The highland forming the western part of the plateau diminishes towards the east. In the longitude of Kwei-yang it bifurcates into a southern and northern watershed with the valley of the Wu-kiang lying between them.

The northern watershed is surrounded on the southern, southeastern and eastern sides by the river Wu-kiang which meets the Yang-tze at Foo-chou.

To the south of Kwei-yang-fu the southern watershed runs in an easterly direction; in the neighbourhood of Too-zuen-fu it suddenly turns towards N.N.E. The eastern scarp of the watershed is steep and well-defined (3500ft. to 4500ft.) and probably extends continuously to the gorge district of the Yang-tze. By this remarkable, extensive step the plateau of Kwei-chou descends to Hunan, just as the Mongolian plateau descends to Manchuria by the Khingan step. In the neighbourhood of Chen-yuan, the river Yuan cuts picturesque gorges mimicking those of the middle Yang-tze region but in a smaller scale: Cliffs rise to a height from 400ft to 500ft; waterfalls appear in succession along the course of the river; underground rivers and caves are of frequent occurrence.[154] These features combine to produce charming scenery.

The Tung-ting basin
and the adjacent districts

The northern part of the Tung-ting basin is characterized by a large number of lakes and marshy ground. In the southern part of it an extensive area is occupied by the shallow lake of Tung-ting. The river Yang-tze enters into this region from I-tu on its N.W. border. It flows southeastward as far as the mouth of the Tung-ting lake, thence the river suddenly turns to a northeasterly direction, separating the hilly region on its southeastern side from the marshy lowland on its northwestern side. After making a peculiar loop at Jin-ko, the river again runs in a N.E. direction till it meets the water of the river Han at Hankow. To the north of the city of Hankow a sharp bend makes the river once more to take a general southeasterly course towards Kiu-kiang. From Hankow to Kiu-kiang four times the river assumes a local W.-E. course, each of which corresponds to a stretch of hill spur trending W.-E.

In the neighbourhood of the lake Tung-ting hills begin to appear on its western, southern and eastern sides. These hills gradually increase in height as they recede from the margin of the lake. They possess rather irregular contours and form watersheds between three river valleys of Hu-nan.

(I) The Yuan-kiang valley. The source of the river Yuan lies in the eastern part of the Kwei-chou plateau and the northern foot of the Nan-ling. Proceeding north-north-eastward, ~~it~~ the Yuan cuts gorges in the neighbourhood of Chen-yuan: ~~further N. E. it~~ then pursues a somewhat sinuous northeasterly course, until finally it enters into the lake Tung-ting at its southwestern corner. (2) The Tsze-kiang valley. This valley is situated to the west of the Yuan-kiang valley and the east of the Siang-kiang valley. The river Tsze descends from the Nan-ling range on the southern border of Hu-nan. In the upper part, the river flows northward. From the west of An-hwa, it suddenly takes an easterly course, and enters into the lake Tung-ting at its southeastern corner. (3) The Siang-kiang valley. The river Siang also descends from the Nan-ling range. But unlike the other two, its course is almost strictly S.-N., being parallel to the divide between the province of Hu-nan and Kiang-si, i.e., the watershed between the Siang-kiang valley and Gang-kiang valley. The latter is connected with the Po-yang-hu basin and therefore belongs to a different physiographical region.

The material brought down by these rivers is enormous in quantity. According to the Chinese official record[189] the land surrounding the lake Tung-ting, is gaining several million mao per annum at the expense of the lake. It seems to be highly probable that all the isolated lakes in the Tung-ting basin were originally connected by a continuous sheet of water. Subsequent infilling during very recent geological time has been responsible for the growth of the cultivable land lying between the remnants (the isolated lakes) of the ancient extensive lake.

CHAPTER III

GEO-MORPHOLOGY

The study of the successive physiographical stages in northern and central China has enabled Bailey Willis to recognize different cycles of erosion during the last continental period of that country. Although this subject is extremely fascinating in a country like China where the geological development has been essentially continental, and revolutionary morphological changes of the land-surface have taken place several times since the Jurassic period, (p237) The available data and the space of this thesis do not admit the writer to enter into the detailed discussion. Only the more important conclusions drawn by Willis are briefly indicated below.[156]

Northern China

Four successive physiographical stages have been distinguished by Willis in northern China.

(I) Pei-tai stage-A very aged form of peneplain is seen on the high plateau of the Wu-tai-shan and elsewhere in eastern Asia. Willis regards the period during which this peneplanation took place, as the first stage of the last continental period in northern China. He calls it the Pei-tai stage.

(2) Tang-hsien stage An eroded surface with moderate relief is well developed near Tang-hsien, Chi-li. The peneplain resulting from the Tang-hsien cycle of erosion is apparently less mature than that from the previous Pei-tai cycle of erosion.

(3) Hin-chou stage This third stage is one of aggradation in northern China. The deposition of loess began at the beginning of this stage. Attributing the production of the desert waste to the climatic change at the end of the Tertiary time, Willis assigns this stage to the opening of the Pleistocene epoch, but he also remarks that it may date back to the Pliocene time.

(4) Fen-ho stage Judging from the young features of the canons cut by the river Fen in Shan-si, Willis believes that this fourth stage is the most recent one.

Central China

According to Willis only two stages of physiographical change are recognizable in central China.

(I) Tsing-ling stage The present Tsing-ling range is supposed to be built at the end of this stage. Willis states that the ancient peneplain is still occasionally seen on the summit of the same range; and that it is difficult to correlate the Tsing-ling stage with the stages which he is able to distinguish in northern China.

(2) Yang-tze stage   Following the Tsing-ling stage is the Yang-tze stage which, according to Willis, is equivalent to the Fen-ho stage in northern China.

<u>Some remarks on the development of the Yang-tze-kiang.</u>

Commenting on the hydrographic system of the Red Basin of Su-chuan and western Hupeh, A. Kniep[37] speaks of the advanced peneplanation of the middle Yang-tze region, and the meandering of the river without close connection to the rock-structure; while Abendanon writes: "The indifference of the course of the middle Yang-tze to the general land-structure rising from south to north, might account to the antecedent theory. On the other hand, the bending round of the Yang-tze near Wan-hsien, from a general N.N.E. to an E.N.E. course, in complete accordance to the turn of the anticlines of the Red Basin against Tsing-Ling-shan, seem to bear against this theory, for here the river has followed the mountain structure".

From the remarks made by Kniep, we would gather that the middle Yang-tze has already reached its base level of erosion; but this idea is contradicted by the fact that swift current continuously pours down from the gorges, and does the work of corrasion and abrasion in an energetic manner; indeed the river maniffests every youthful feature. Moreover the course of the Yang-tze in the gorge district, is sometimes parallel to the axes of the folded strata, (above Ba-tung-hsien) and sometimes perpendicular to them, (atthe I-chang gorge) showing that it does bear some connection to the rock structure. Therefore we cannot regard Kniep's remark either as an anouncement of facts or some preliminary suggestion which might evolve to an acceptable hypothesis. Abendanon's account quoted above is much more ~~congruent~~ in accordance with the observed facts. To account for the existing hydrographic system in the upper and the middle Yang-tze region Abendanon writes that it is probably due to the combined effect of antecedent and regressed rivers. This hypothesis suffers the criticism of being too elastic; it only gives us a vague impression about the development of the mighty river.

SECTION I

P H Y S I O G R A P H Y.

S E C T I O N II.

G E N E R A L G E O L O G Y.

CHAPTER IV.

S T R A T I G R A P H Y.

Introductory.

Selection of data --- In endeavouring to gather various kind of adequate information to form the framework of this chapter, two principles are constantly kept in view: (1) the data must be reliable in so far as the writer is able to judge. (2) They must be fairly typical over a rather wide area, in other words they may be taken as representatives, so to speak, of the stratigraphical facts of a region in which geological conditions are essentially similar all over the area. That kind of information which does not satisfy both of these two conditions is discarded. From the second it follows that observations of merely local importance, are left out of consideration. It would be against the original intention for the preparation of this work, if every detail of known facts were to be included.

Sometimes the records made by different observers at different times in the same district tend to confirm one another, but in other cases they do not entirely agree or may even conflict. In dealing with such cases the writer thinks that the safest and the most unbiased way is to cite all the accounts of observations, as far as convenience of description permits, in the original form; and leave them to fight their own battle.

In all cases, attempt is made to distinguish the observed facts from deduced data, so that even when the deduction fails, which may be expected to occur as our knowledge grows, the established facts would not suffer any distortion or be otherwise affected.

The treatment of each system or a group of systems, except the post Jurassic, is divided into three parts: (1) General remarks on the outstanding points characterizing the particular system or a group of systems are made. A short historical account concerning the establishment of any system peculiar to China is also inserted under the same heading. (2) The stratigraphical sequences determined by different observers in various regions are dealt with under the heading of field observations. These form the fundamental data from which all deductions are to be derived. In this part of the work, save the general arrangement, translation, para-phrasing and wording, the writer's own opinion is very little concerned. The description of each unit or a series in a sequence is found sometimes too brief and sometimes too full of superfluous material. In the former case, the description is amplified, if possible, by adding further notes which are drawn from one and the same author's work but not necessarily from the same part of it. In the latter case, material that appears to be superfluous has been omitted, the writer must accept the responsibility for such abridgement. (3) Evidence and arguments (if any) are brought forward under the heading of correlation or summary, as the case may be, in which a certain amount of the writer's opinion is involved.

By far the greater number of fossils that have been described and figured by different palaeontologists are mentioned in connection with the description of the geological formations which yield them or with reference to the exact locality from which they have been collected. The large lists of fossils appear at first sight, to be out of proportion in this thesis; but that this is not really so is seen when it is realised how vital a part each species may play in the determination of age and the correlation of strata both in the present and future stratigraphical study in China.

The weight of any inference drawn with regard to the question of age of certain strata must ultimately depend on the authentity of the specific determination of the fossils that they yield. With regret, the writer considers himself not in a position to take part in palaeontological discussion; nor is it desirable to bring such discussion into this thesis. The specific and generic names given by different palaeontologists are arranged in separate lists with reference to the original papers in which the actual specimens are described and figured.

Terms, notations, etc. used in this section ---- In northern China where stratigraphy is comparatively simple, a number of peculiar systems has been recognised by Richthofen, Bailey, Willis and others. The names given to these systems are adopted in this thesis either in their original sense or slightly modified by the writer. In both cases, they are clearly defined under the heading of General Remarks of each system or a group of systems. The application of these peculiar terms in southern China does not seem to be possible, for there the stratigraphical record is much more complete and complicated than that of northern China. The writer has attampted to extend the use of these terms to a large part, if not the whole of the country with the object of simplifying matters relating to stratigraphical correlation; but reports after reports from southern China have forced him to abandon this plan.

Having made no personal field observations, I feel scarcely justified in classifying Chinese geological formations under new systems, though frequently such a procedure appears to be desirable. To do so it would necessitate the introduction of new terms, which is too heavy a responsibility for the writer to accept, at all events at present. On the other hand I do not hesitate to assert the presence of certain large groups of formations in China equivalent to those developed in Europe and North America during different periods on the strength of palaeontological evidence. Being governed by these circumstances, a suitable method for denoting a group of formations with respect to their approximate age becomes necessary. To form the heading under which each group of formations is to be described, I use the names of definite geological period or periods combined with a hyphen (-) and dots (...). A hyphen between the names of two periods means the duration of the two periods, while dots are meant to signify the uncertainty of the chronological extension of a group and yet an extension not far from the period to which the dots are attached, e.g. CAMBRIAN-MIDDLE ORDOVICIAN... represents a group of formations, the lowest member of which was formed at the beginning of the Cambrian time, while the uppermost member may extend to some short period after the close of the Middle Ordovician. It is hardly necessary to say that such groups are largely divided for the convenience of description.

Utmost care is taken to prevent straining the original statements recording field observations, when they are subjected to reconstruction. A number of vague technical terms frequently occur in French and German works, e.g. French Geologists seem to use the word "schist" sometimes for shale and sometimes for slates, while German writers use the term "schiefer" in various senses. To avoid confusion and vagueness I render all these terms into what appears to be the most appropriate English word for each particular case and put the original in bracket.

All stratigraphical sequences are arranged in descending order and numbered from the base of a sequence upwards. The lettering or notation of each set of beds in a sequence and the standard of measurements quoted or abstracted from various works are kept in their original form at the expense of uniformity of style. The object is to attain the greatest facility for tracing the information to its original source. The standards used for measuring distance and thickness are English mile, kilometer, li, foot and meter.

English, French and German writers all have their peculiar ways of spelling Chinese names. They may not exactly convey the original Chinese pronounciation but the writer thinks it desirable not to alter them for the same reason as stated above. In this connection two exceptions, however, occur: (1) "Ch" attached to the beginning of a syllable given by French writers is replaced by 'Sh' in this thesis. (2) 'J' placed at the beginning of a syllable given by German writers is replaced by 'Y'; e.g. 'Chann' is transformed into 'Shann' and Jen-tsai-yi is transformed into Yen-tsai-yi.

Before proceeding to deal with each system or a group of systems, I here introduce a table showing the general stratigraphical succession in different parts of China, and the lateral equivalents of each formation. It is based on the conclusions drawn by different geologists and palaeontologists mentioned in this chapter, and also, to a certain extent, on the writer's opinion.

Notations in the table:

Conformable junction between two formations is denoted by ——

Unconformable " " " " " " " ~~~

Uncertainty of the nature of the junction between two formations is denoted by ... ... -------

[See the separate Correlation table]

P R E - C A M B R I A N

or

The Pre-Sinisian Systems.

(1) General Remarks.

Rocks classified here under the term pre-Sinisian systems are characterized by their stratigraphical position below the plane of pre-Sinisian unconformity, or the lowest stratum of the Sinisian system as defined later. Since we have good reason to believe that the lowest Sinisian bed is equivalent to the lowest Cambrian bed, we may regard the pre-Sinisian systems in China as equivalent to the pre-Cambrian systems in the other parts of the world. It is, however, important to note that, although the Pre-Sinisian systems occupy as a whole, the lowest stratigraphical position in Chinese geology, they are not necessarily the oldest rocks; for intrusions of much younger age than Cambrian are intermingled with the true pre-Cambrian formations.

The pre-Sinisian systems include rocks of various kinds - igneous, sedimentary and metamorphic. The last mentioned is more predominating in these systems than in any others: Nearly every member of the pre-Sinisian systems shows signs of metamorphism in the wider sense of the term. They are often so badly altered that one can hardly make out whether they were of sedimentary or igneous origin. ~~But~~ Nevertheless highly metamorphosed rocks in China do not necessarily belong to pre-Sinisian systems; for large masses of schists probably of palaeozoic or even mesozoic age occur in the eastern Tsing-ling-shan,[157] according to Bailey Willis; and palaeozoic gneiss and schists showing a pre-Sinisian aspect are exposed at many localities in S.E. Yun-nan, according to J. Deprat,[6] and others.[39]

Pre-Sinisian rocks are generally unfossiliferous for all we know. Even in those members which are most favourably disposed to preserve organic remains, such as shales and limestones, no more than traces of doubtful fucoidal inpressions and enigmatical worm tracks have been found. Curved and minutely contorted laminae of flints are reported to occur in pre-Sinisian strata. They are compared by Willis with Cryptozoan Proliferum, Hall.[201] But he also suggests that such peculiar structure seems to be more likely due to mechanical cause rather than organic origin.

Important exposures of the pre-Sinisian rocks are chiefly known in northern China in the provinces of Shan-tung, Chi-li, Shan-si, the Nan-shan region, and the Tsing-ling range. But in southern China they are also exposed here and there: The principal exposures are in western Su-chuan or the Si-Shiu ranges, middle Yang-tze, northern An-hwei, southern Kwang-tung and probably in some parts of the southeastern coast.[32]

On account of the grand development of the pre-Sinisian or pre-Cambrian rocks in northern China, it seems to be desirable to subdivide them into different systems. Such systems, when we can consider them as well-established, would be not only of local value but would ~~bear much importance~~ throw much light on the early geological development of the world. At present all that we know for certain during the pre-Cambrian time in China is that prolonged sedimentation was punctuated by earth movements. The nature of the geological processes in this ancient time does not appear to have differed materially in kind ~~and~~ not probably ~~nor~~ in degree from that ~~which may be said in~~ has been recognized common to the later geological processes since Cambriam ~~ti~~ time. Although the available data are insufficient to warrant the establishment of different pre-Sinisian systems purely from stratigraphical point of view, the three principal lithological and structural types of the pre-Sinisian rocks exposed on the S.E. flank of the Wu-tai-shan seem to invite us to attempt, at least provisionally some chronological division of the pre-Sinisian period.

Bailey Willis has used the terms "Eo-proterozoic"[158] for representing the early part of the Algonkian time and "Neo-proterozoic" for the later part of the same period. Obviously he uses the term proterozoic in a different sense from what has been defined by Prof. C. Lapworth who has contracted the term as protozoic, and used it to indicate the lower palaeozoic groups. Regarding the marbles and schists in the fundamental complex, the lowest group of the pre-Sinisian systems (see pp 55, 73) as altered sediments, the writer ventures to call these sediments Eo-proterozoic formation; Accordingly he regards the Eo-proterozoic of Willis as Meso-proterozoic and uses the tern Neo-proterozoic in the sense as originally defined by Willis. According to this scheme, we have three periods in pre-Sinisian or pre-Cambrian time: The oldest which is represented by the highly altered sediments intermingled in the fundamental complex, is eo-proterozioc, the second is meso-proterozioc and the third neo-proterozioc.

(II) Field Observations.

N.E.China.

Western Chi-li and Northern Shan-si.

In the district of Wu-tai-shan and the adjoining regions, Willis and Blackwelder recognized three groups of pre-Sinisian formations:[159]

C. Hu-to system.

B. Wu-tai system.

A. Tai-shan complex.

A. Tai-shan complex The rocks of the Tai-shan complex are, according to Willis and Blackwelder, broadly exposed in the vicinity of Tang-hsien and Fou-ping-hsien, Chi-li, and along the divide between that province and Shan-si. They occur also in the dissected upland west and south of the city of Hin-chou, on the northwestern foot of the Ki-chou-shan, and more extensively along the northern base of the Wu-tai mountains.

In the Tang-hsien and Fou-ping-hsien district the nature of the complex is in general the same, and grades from "gneissoid granite" into mica-schist. It is usually quartzose with a small amount of hornblende or biotile. Lenticles of amphibole schist and biotile schist, varying from a few inches to a few feet in size, are numerous at places. Small masses of course white marble with or without streaks of white mica occur in association with mica schist. In the more quartzose variety of the complex there are few or no felspars. Parallel layers of acidic composition, possibly owing their origin to early intrusion, are in some cases responsible for the banded structure; in other cases they give rise to peculiar designs when folded or contorted. (see section)

Intruded into the complex mentioned above, there are granites, aplites, granite-porphyries, felspar porphyries, and altered basic rocks generally classified as greenstones. The acid rocks occur as dykes of varying size in the mountains near Tang-hsien and the vicinity of Fou-ping-hsien. Some of the aplites appear to be apophyses of large granite porphyries. Veins of quartz and pegmatite traversing the complex are frequently seen. They may be genetically connected with the granite. In the west of Fou-ping-hsien hornblende becomes the prominent constituent of the pegmatites. The basic dykes are well exposed in the region of Fou-ping-hsien and Tang-hsien. Their number and thickness increase towards the Wu-tai-shan. One dyke of greenstone exposed at the south-east end of the mountain west of Wan-hsien, is as wide as 400 ft. These basic rocks are altered to various extent, ranging from those which hardly show any sign of strained condition to epidiorite and hornblende schist.

On the northwestern side of the Wu-tai-shan the prevailing rock is a reddish mica-gneiss traversed by schistoze greenstone. Richthofen first reported its occurence in this district, and he regards it as basal gneiss.[30] Willis identified the same rock during his hurried journey.[160]

The red and grey granite exposed in the Hin-chou district, are composed of orthoclase, biotile and blueish grey quartz. Although they themselves do not appear to have been highly metamorphosed, the greenstones which have intruded into them are usually schistose.

B. <u>Wu-tai system</u>. In the Wu-tai district, S.E. of Shi-tsui, Willis and Blackwelder observed soft grey mica schist overlying the typical Tai-shan complex. This schist is quickly followed upwards by coarse-grained felspathie quartzite. This quartzite is regarded by Willis as the first indisputable sediments that overlie the gneissic complex in the Wu-tai district. Owing to the advanced metamorphism that both the quartzite and the gneiss have suffered, Willis and Blackwelder were unable to determine the actual junction between the two. Nevertheless they state that the whole sequence of rocks lying above the soft grey mica schist is distinctly stratified, and the strata are much less intensely metamorphosed than the underlying complex, Therefore they infer that the junction between the Tai-shan complex and its overlying series must be an unconformable one. They call the overlying series the "Wu-tai system".

The rocks belonging to the Wu-tai system are well exposed along the S.E. flank of the Wu-tai-shan. Their apparent succession was observed by Willis and Blackwelder.[161] The following sequence is not exposed along a single section, but is a combination of the exposed succession of strata in three sections, viz. Shi-tsui section, (1 to 19) Shan-ho-miau section. (20 to 26) and Wu-tai-shan section

(27 to 33) The numbering of the strata given below is not in accordance with the interpreted sequence as given by Willis and Blackwelder, but is intended to denote what appears to be the apparent succession of the Wu-tai system on the southeastern flank of the Wu-tai-shan as observed by the same geologists (see section No. 5)

34. Gneiss composed of quartz, felspar, muscovite and chlorite; metamorphosed to an advanced stage, partial recrystallization being recognizable. This gneiss grades into a belt of grey muscovite-schist which passes downwards insensibly into the underlying chlorite. It is exposed on the northern part of the peak of Pei-tai; and is not shown in the section.

33. Chlorite schist appears to be monotonously uniform over a large area of the upper part of the Wu-tai-shan. Close examination however shows that it is sometimes massive, not well cleaved, and sometimes a true phyllite. All the mineral grains may be composed of pure chlorite or may be mingled with biotite or quartz.

32. Following the chlorite schist, quartzite and sericitic elements gradually appear. The rock changes from finely laminated quartz-sericitic-schist to grey fissile schistose quartzite with pink felspars.

31. The above arkose series gradually merges into a conglomeratic schist consisting of quartzite and granite pebbles of various size, embedded in a matrix of chlorite schist or greywacke schist. The pebbles are severely deformed, flattened, elongated with their long axes lying in the plane of schistosity.

30. Grey quartz-mica-schist.

29. Arkose schist followed by green schistose conglomerate. (Note. The above two beds are essentially similar to 32 and 31, the recurrence of these beds, according to Willis, suggests the existence of a thrust plane between 31 and 30.)

28. Hard reddish brown and grey banded quartzite and siliceous marble with thin layers of sericite-phyllite and chlorite-schist. The quartzite is locally conglomeratic containing large well rounded pebbles of quartz and quartzite.

27. Banded grey quartzite and siliceous marble with thin layers of slates and local beds of hematite near the thrust described below, and bands of jasper exposed to the N.E. of the Tai-shan-ho.

Near the temple of Shan-ho-miau, there is a thrust. The general trend of the "outcrop" of the thrust plane is more towards the east than the strike underlying beds which strike N.E.

26. White marble with thin layers of Garnet-schist.

25. Alternation of chlorite and biotite schists with schistose brown quartzite.

24. Pure white marble massive and medium-grained.

23. Alternation of garnet-biotite-schist and chlorite schist with banded grey and reddish brown quartzites. The quartzites are more or less schistose.

22. Coarse-grained white marble with thinner strata of garnet-schists.

21. Biotite-garnet-staurolite-schist.

(Note. 26 to 24 and 24 to 21 are interpreted by Willis and Blackwelder as two limbs of a syncline.)

20. Massive grey "Augen-gneiss" exceedingly uniform in texture. The bands of the gneiss are so arranged that as if they were parallel beds between the overlying and underlying schistose sedimentary strata in a conformable sequence.

(Willis is inclined to regard this gneiss as a metamorphosed granitic mass, intruded into the sedimentary Wu-tai system)

19. Moderately schistose pink quartzite with seams of mica-schist.

18. Steel-grey hard magnetite-quartzite, highly magnetic, including bands of jaspilites and jasper.

17. Mica-schist and gneiss.

16. Amphibolite.

15. Mica-schist.

14. Massive, spotted, greenish amphibolite. Large crystals of hornblende often form a matted network in the schistose light-greenish matrix.

13. Muscovite-schist and gneiss.

12. Arkose schists with pink felspars.

11. Alternation of grey mica-schist and gneiss with thin layers of chlorite schist. Here the bedden rocks are hidden from sight by the river bed.

10. Massive, brown-banded quartzite having fairly uniform texture.

9. Dark biotite schist.

8. Micaceous quartzite.

7. Biotite schist with bands of pink quartzite; some layers rich in red garnet, others in staurolite and scapolites. In the cleavage planes large flakes of mica occur.

6. Felspathic quartzite with diminishing quantitiesof mica following downwards.

5. Fine grained biotile schist.

4. Dense, grey micaceous quartzite.

3. Pale grey and pinkish quartzite with large crystals of pink felspars. The whole series is severely deformed.

2. Biotite Schist.

1. Tai-shan complex.

The beds 2 to 19 all dip N.W. with increasing amount: the lower ones dip about 30° N.W. while the upper strata dip as steep as 70° N.W. This fact is considered by Willis & Blackwelder as an indication of a synclinal structure. They further argue that the southern and the northern ends of the Shi-tsui section are alike inasmuch as both of them are decidedly quartzose, and containing biotite schists: that the black magnetite-quartzite (18) may represent the ferruginous quartzite (10) which probably became magnetic through losing a part of its oxygen under the influence of the intrusion, the augen gneiss. The lowest members of the northern limb of the inferred syncline were probably cut off by the intrusion according to Willis & Blackwelder. In connection with the question of possible megnetization of ferruginous material by intrusion, the writer considers a certain experiment conducted in the University of Birmingham under the direction of Prof. T. Turner[205] as s substantial proof. It has been shown that non-magnetic hematite and other classes of iron ores can be rendered magnetic by roasting.

In discussing the genesis of the bed (2), the biotite schist, Willis & Blackwelder suggest the following alternatives: Firstly, it may be regarded as argillaceous deposit, being subsequently subjected to intense metamorphism; Secondly, to regard it as a part of the underlying Tai-shan complex. In the absence of further data, it is difficult to judge which is nearer to the truth.

On the North Western side of the Wa-tai-shan Willis noted mica and quartz schists dipping vertically in a canon. On the North-western side of this exposure, and close to it, the same geologist saw massive granitoid gneiss. The actual junction between the two was not observed by him. The schists in the lower horizon contain large pebbles of quartz and quartzite. They pass into pure chlorite-schist towards the summit of the mountain.

On the southern slope of the Wu-tai-shan, Richthofen observed a bedded series which he calls "Wu-tai series", (Wu-tai schichten) as he followed the Wu-tai-ho downwards. The strata strike N.E. and dip N.W. at 45°. The following are the observed sequence:-

a. A very thick series of alternating beds of green schist, grey slates (Tonschiefer) and quartzite.

about 2000 feet. (
b. Grey-green, slaty (thonige), highly schistose strata.
c. Conglomerate with intercalation of grey schists. The pebbles of the conglomerate consist of quartz, quartzite and green schists.

600 feet. (
d. Metamorphosed, felspathic, and shaly sandstone forming a semi-crystalline rock, with individual beds 4 to 5 feet thick.
e. Very hard and very coarse conglomerate consisting of quartzitic pebbles.

f. Hard, pure quartzite of gray-white colour. 800 ft.

g. Quartzite with interbedded shaly sandstone, gray and green schist, conglomerate etc. Course-grained, green minerals belonging to the hornblende group occur in these rocks. Chlorite also plays dominant parts.

Richthofen remarks that these strata are very difficult to classify. They attain, at least, a total thickness of 2500 ft. The lower part of the sequence was not followed by him.

After some consideration, partly from lithological and partly from structural point of view, Willis & Blackwelder classify the Wu-tai system, as exposed on the S.E. flank of the Wu-tai-shan, into three series; and place them tentatively in the following order:-

c.	Si-tai series	beds 28-33
b.	Nan-tai series	" 21-27
a.	Shi-tsui series	" 2-19

The nature of each series may be briefly summarized as follows:-

a. Shi-tsui series. - This series consists of schists, gneiss and quartzites. The rocks are unmistakably of sedimentary origin. The apparent thickness of the series is estimated at 12,000 ft. provided there is no repetition of the members through folding or thrusting. But according to Willis & Blackwelder, the structure of the strata is probably a monoclinal fold; the thickness then would be reduced to 6,500 ft. of which 4,000 ft. being attributed to the lower alternation of quartzites and schists.

b. Nan-tai series. This series largely consists of dark quartzite and siliceous marble with subordinate amount of schists. The apparent thickness from the base of the bed (21) to the thrust plane is reported to be 2,000 ft. The actual thickness is probably much less because of the local folding of the members.

c. Si-tai Series. This series is characterized by massive chlorite-schist. Towards the lower part of this series the constituents become coarser and coarser, till the rock is distinctly conglomeratic. The pebbles of the conglomerate are such as the Nan-Tai rocks would furnish. They are in some localities severely deformed, while in others their original shape is more or less maintained in a schistose matrix.

C. Hu-to system Although Willis & Blackwelder assert that the rocks that they have classified under this category constitute a unite, and that an unconformity exists between this system and the underlying Wu-tai system, they did not observe the actual unconformable junction during their reconnaissance in the Wu-tai district; nor any other geologist has made special investigation on this point. The inference drawn by Willis & Blackwelder is based on the fact that rocks belonging to the Wu-tai system are all intensely metamorphosed, while those belonging to the Hu-to system are only slightly altered; that the general dip of the Wu-tai strata often approaches verticality, but that of the Hu-to rocks is, as a rule, gentle. They further state that the unconformable junction may be seen at the summit of the Nan-tai, the southern peak of the Wu-tai-shan; and that we may find the Hu-to rocks resting directly on the Tai-shan complex in the Wu-tai district.

The following exposures of the Hu-to rocks were observed by Willis & Blackwelder:

Near Tou-tsun. Between Tou-tsun and Wu-tai-hsien, Shan-si, a group of slates with portions of the overlying limestone are well exposed. The base of the slates has not been observed. Willis & Blackwelder call the slaty group Tou-tsun slates. They made out the following sequence: (see section No. 9)

e. "Gray pinkish limestone, accompanied by a light coloured limestone breccia in an unknown relation".

d. "Dark purplish argillite".

c. "Gray and buff limestones, dense or finely crystalline. Contain parallel laminae of flint, which are often curved and become prominent on the weathered surface . . . . 150 ft."

b. "Purple argillite with thin beds of limestone and one or two quartzite. The argillites show mud cracks and are not schistose . . . 250 ft."

a. "An unknown thickness of gray argillites which are usually slaty. Like the slates of Li - [illegible]an these frequently contain grains of hematite and local thin layers of red dolomite".

East of Liu-yuan. In the east of Liu-yuan and the south of the Nan-tai-shan, there occurs a series of earthy gray phyllites with intercalation of thin layers of crystalline dolomite. These phyllites are well cleaved. Crystals which appear to be pseudomorphous of hematite after magnetite, are often seen in the cleavage planes. 2·5 miles S.E. of the village of Liu-yuan, the phyllites are brought into contact with a syncline by a thrust from the west. The syncline is formed by strata of white quartzite and limestone with layers of phyllites. The quartzite is locally conglomeratic. Willis & Blackwelder identified the gray phyllites as the Tou-tsun slates. (Section No. 6)

Near Tung-yu. East of Tung-yu, Shan-si, a low range largely composed of limestones with interbedded soft slates is mentioned by Willis & Blackwelder. The prevailing colour of the limestone is dark gray, but light gray, pink of even buff layers are frequent. Willis & Blackwelder call this limestone group, the Tung-yu limestone. Towards the northern part of the range purple slates appear to be overlain by impure limestone which is often pink or bright red. Further north, red, white and purplish gray quartzite containing layers of conglomerate, at least 500 ft. thick, dipping northward, lies upon purple slates. The junction is probably a thrust according to Willis & Blackwelder. (See section No. 7).

W. & S.W. of Tung-yu, there are low anticlinal hills rising above the plane of the Huang-tu or loess. Some of them are composed of limestone, others, of dark schistose slates with reddish lime - stone and quartzite. The massive gray limestone with shaly strata forming the mountain spur, N.W. of the town of Tung-yu are apparently the continuation of the limestones exposed in the low ranges, east of the same town. (Section No.8)

Tou-tsun district. Seven miles east of Tou-tsun there is a synclinal ridge in which are exposed strata of gray, buff limestones with shaly rocks and occasional white quartzite. On the S.E. these synclinal strata thrust upon the Sinisian limestone: towards the N.E., the ridge ends in a canon which separates it from the Nan-tai. On the N.E. side of the cañon, Willis & Blackwelder observed rocks from a distance dipping steeply northwards, presenting similar aspect of the Wu-tai rocks. Therefore they suggest that the unconformable junction between the Hu-to system and those lying underneath it may be found along the slope of the Nan-tai.

Northern slope of the Ki-chou-shan. South of the Ki-chou basin, and along the northern foothills of the Ki-chou-shan, belts of the Tung-yu limestone are repeatedly exposed between belts of granites and schists of the fundamental complex or the Tai-shan complex. The different belts of rocks being obliquely cut off across their westerly extension by a mighty fault, the Ki-chou-shan fault, the exposures of the Tung-gu strata arrange themselves en echelon.

Summarizing the observations with regard to the Hu-to rocks in the districts near the north-eastern boundary of the province of Shan-si, Willis & Blackwelder draw two divisions:-

Upper Tung-yu series.

Limestones with slates . . . 3500' to 5000'

Lower Tou-tsun series.

Slates with limestones . . . 3000' or more.

Near the Wu-tai district, Williss & Blackwelder have distinguished a peculiar series of limestone formation which cannot be readily grouped with any other limestones occurring in the district. They call this formation "Ta-yang limestone". The Ta-yang limestone is essentially a dense, gray, argillaceous or siliceous and sometimes pure limestone containing numerous characteristic layers of usually black but occasionally gray or white flints. At the base of the limestone a thin layer of shale up to 30 ft. thick is generally present. Seams of quartzitos and even schists occur in the limestone. It is readily distinguished from the overlying Sinisian limestone which is free from flints and quartzites as exposed in the Wu-tai district.

In the North and West of Wan-hsien, S.W. Chi-li, Ta-yang formation rests on a fairly even floor of the Tai-shan complex, and is apparently overlain by a series of soft quartz-biotite-schist with layers of white quartzite. The total thickness of the Ta-yang formation in this district is estimated at about 1,200 ft. (see sections No.10 No.11).

In the vicinity of Tang-hsien, near Nan-tang-mei, Ta-yang limestone again lies upon the Tai-shan complex. Willis gives the following sequence:[162]

5. Dark purple, hard shale more than 60 ft.

4. Quartzite 50 ft.

3. Conglomerate composed of well rounded pebbles of black, white and banded flints in a hard siliceous matrix. The matrix is ~~observed~~ sheared on planes striking N.30°W., and dipping 70° to 85° N.E.. 100 ft.

2. Ta-yang limestone.

1. Tai-shan- complex.

The Ta-yang formation is widely distributed in S.W. Chi-li. It generally occurs in association with the Tai-shan complex, or actually overlies it. From the village of Si-ta-yang it extends westward to the city of Kiu-yang-hsien, forming low hills which are half buried by the superficial Huang-tu. Good exposures were noted by Willis in the hills east of Wang-kuai-chou, and at the summit of the mountain about a mile east of Fou-ping-hsien.

Near Hwo-lu-hsien, south western chi-li, a section of limestones is exposed in the Hsi-ping-shan mountains bordering the plain of S.E. Chi-li. The succession of strata ~~observed~~ described by Richthofen is cited by Willis for comparing the development of the pre-Sinisian sedimentary series. The following is Willis's transalation:-

9. "Firm sandstone, white and gray".

8. "Crystalline limestone".

(Interruption)

7. "Greenish gray, brightly coloured, ringing thin bedded siliceous limestones; interbedded with various sorts of strata".

6. "Globulitic and conglomeratic ("Wurmkalk") limestones".

5. "Thin-bedded limestone, red and green."

4. "Red shales".

(Interruption)

3. "Crystalline limestone with nodules and layers of flint."

(Interruption)

2. "Alternation of crystalline, thin-bedded limestone, including thin layers of flint, with quartzite, epidote rock, red sandstone, etc."

(Interruption)

1. "Gray crystalline limestone".

NORTHERN CHI-LI

Gneiss & Schists. According to Richthofen, crystalline schists and gneiss occur in the region east of Yung-ping-fu, but they disappear towards Peking. Between Yung-ping-fu and Peking Richthofen only observed one exposure of gneiss and schists on the west of Tong-tchou.

The occurrence of gneiss and schists near the Mongolian border is mentioned by Richthofen, Obrutchov and others. These crystalline gneiss and schists extend towards the west and occupy large area in northern Shan-si. From Urga to Kalgan Obrutchov observed belts of schists, gneiss, and crystalline limestone occurring in association with granite. These rocks lie between bands of basalt, rhyolite and porphyries, and generally strike N.E. - S.W.[142]

Nan-kou section. In crossing the Nan-kou mountain from Tshai-tang to Pau-ngan-fu, Richthofen made out the following sequence in which pre-Sinisian rocks occur;-[82]

K. An essentially dark coloured, fine-grained limestone breaks splintery. . . . . . .about 2,000 ft.

i. Globulitic limestone with trilobitic remains 2,000 "

h. Variable strata of red slates (Schieferton) and limestone with evenly bedded, platy, greenish siliceous limestone lying at the base. . . . . 580 ft.

g. Gray massive limestone, in part fine-grained and crystalline. . . . . 400 "

f. Gray-green and black sandy slates, (Schieferton) partly even and partly curved. Intercalated with the slates are yellow sandstones rich in ironstone nodules. Organic remains are absent except doubtful traces of stem-like bodies. 500 ft.

e. White-gray, fine-grained crystalline limestone with bands of quartzite and occasional flints. . . . . about 2,500 ft.

d. Light brown crystalline flinty limestone, partly pure and partly stratified with thick beds of quartzite. This series is only observable near Fan-shan-pu where the strata rise above the loess plain.

c. The bedded rocks are largely buried under the mantle of loess. At the north of Fan-shan-pu only a bed of rose-red crystalline limestone are visible.

~~was noted by Richthofen.~~

b. Thinly bedded gray-white crystalline limestone which is sometimes schistose. Flints and beds of black quartzite are present.

a. Flinty limestone with thick beds of quartzite. They are sometimes schistose.

Richthofen designates the beds from a to e as "Untersiniesh", and h to k as "obersinisch". As to the beds f.g., Richthofen seems to be rather perplexed in classifying them. In this connection it is important to note that the "Sinisch" system, as established by Richthofen, has been revised by Willis. The reason for the revision is stated in the general remarks on the Sinisian system. The term "untersinisch" as used by Richthofen is not equivalent to the term "lower Sinisian" used in this Thesis.

Shan-tung.

Tai-shan district. In the vicinity of Chang-hia, near the mountain Tai-shan, western Shan-tung, Willis and Blackwelder were ~~are~~ able to distinguish a group of very ancient type of rocks. Their structure is intricate and their stratigraphical position is apparently absolutely basal. They call this basal mass the "Tai-shan Complex". According to Blackwelder, the Tai-shan complex or fundamental complex exposed in the Tai-shan district is classifiable into three groups of rocks:-[163]

(c) Schists and gneisses The schists are mostly dark greenish rocks containing quartzite, hornblende and often with biotite lying in their cleavage planes. They are altered and folded to such a degree of complexity that they leave hardly any clue by which one may infer their genetic relation. The gneisses are usually composed of quartz, orthoclase and biotite with a few other accessory minerals. Hornblende and sometimes chlorite are present. The proportion of ferromagnesian minerals varies from place to place. The structure of the gneisses may be so coarse as to show large bands ranging from a few inches to a few feet, with phacoids of felspars or it may be as fine as only to reveal the schistosity under a microscope. In the field these structures can be traced to a varying extent, and one merges into the other by insensible gradation.

The composition of the schists has led Blackwelder to suppose that they might be of igneous origin but he also says that the available data do not preclude the idea that they may be partially sedimentary in origin. The gneiss are believed to be a granitic intrusion, or intrusions into the older schists. This view is supported by the fact that large masses of the schists are sometimes included in the gneisses. Dyke-like masses of biotite schist are seen to traverse both the gneiss and the schist. It is uncertain whether they are metamorphosed later intrusions. (see section)

(b) Granite. A group of granite composed of quartz, orthoclase and biotite with prevailing red colour and medium grain is exposed in many places in the vicinity of the Tai-shan; but those which occur at Tai-shan itself are coloured grey due to the presence of epidotes and chlorites. No hornblende is present in these granites, and they are apparently less metamorphosed than the gneiss. This latter fact suggests their younger age and therefore intrusive nature. Off shoots and veins of quartz and pegmatite often radiate from a central mass, and cut through the older gneiss and schist.

(a) Igneous rocks other than the granite also occur in the Tai-shan complex. They are as a rule, little altered. One dyke of doleritic habit occurring on the east of the Man-to-shan traverses the red granite, and it is cut off by the lowest Sinisian stratum.

Throughout the Tai-shan district, the Tai-shan complex is always overlain by the Sinisian formation wherever the junction between this group and the younger sedimentary strata was observed by Willis and Blackwelder. Rocks which may be regarded as equivalent to the Wu-tai system and the Hu-to system in the

Wu-tai-shan district, Shan-si, are apparently wanting in the Tai-sh[an] district, Shan-tung.

~~At~~ To the south of Wang-tai, between Lai-wu-hsien and Po-shan-hsien, western Shan-tung, Lorenz found gneissic mica-schist which he regards as metamorphosed "Algonkian Sediment", in other districts in Shan-tung, the same author mentions the occurrence of quartzite and marble of "Algonkian Age". The average thickness of this so-called Algonkian formation in Western Shan-tung is according to Lorenz, only 200 m.[62]

In the neighbourhood of Che-foo,[83] eastern Shan-tung, Richthofen observed micaceous schist covering a large area of the hilly district. The schist is very typical, and often contains abundant small grains of garnet. In the western part of the hill ranges near Che-foo there occurs a massive formation of crystalline limestone with an ill-defined boundary. To the west of the pass on this limestone hill lies a broad sandy plain above which rises a low hill of crystalline schist. The town of Fu-shan-hsien stands on this hill. Southward, the valley extending by the side of the hill ranges near Che-foo comes to an end at Hau-yu (40 lis from Che-foo) ~~wherefrom~~ whence Richthofen followed a sequence of ancient rocks: (section No.17)

> 4. Blueish crystalline limestone strata striking N.E.-S.W. and dipping N.W. The lower part of the limestone contains a large number of intercalated beds of micaceous schist, and green-brown rock. Toward upper part the lithology of the limestone becomes very variable, ranging from thin layers of fine-grained impure limestone to quartzite. At a still higher horizon the micaceous schist completely

disappears. The thickness of this formation is considerable. Throughout the exposure, no folding was observed by Richthofen.

3. Granitoid rock, similar to the formation No.1. in this sequence.

2. White and Yellow quartz-porphyry.

1. Non-calcareous metamorphosed rocks striking N.W.-S.E. and dipping S.W. In some parts of this formation the rock is micaceous, and in other parts, it is granitoid. Schistose and gneissic structures are both known in these rocks.

To the N.W. of Wu-shi-li-pu,(lat 37° 45' N.long. 120° 52! E.) near Teng-chou, Richthofen came across a group of rocks described below. The description of the rocks is arranged in the order as he saw them from S.E. to N.W. the numbering of each series is in accordance with the inferred succession from the older to the younger. (section No. 17)

4. Calcareous metamorphosed rock dips S.E.

5. Eruptive greenstone with hornblende overlain by quartz-porphyry as that of Tsi-shi-li-pu.

4. Very coarse well-bedded crystalline limestone striking N.E.-S.W. and dip S.E.

6. Basalt-cover with olivine and basaltic hornblende.

4. The lower part of the calcareous metamorphic series.

1. Mica-schist, the same formation as that forming the hills of Che-foo. Intercalated with the mica schist are coarse-grained rocks composed of quartz, mica and large crystals of orthoclose and tourmaline, striking N.W.-S.E. The same strike is observed with the mica-schist forming the hills of Che-foo.

Central and Southern Shan-si.

According to Blackwelder, pre-Cambrian rocks occur in almost all of the high mountains visible from the main road running in the plain of Tai-yuan or the valley of the Fen-ho. They belong to two and possibly to three systems, and are essentially the same as those occurring in Western Chi-li and northern Shan-si already described.[164]

In the valley of the Wen-shui-ho, Willis and Blackwelder found gravels and pebbles consisting of black and white hornblende-granite, coarse pink granite, Hornblende-porphyry, basaltic rocks and quartzite of various colours. These rocks are presumably derived from the rugged Shi-hsia-shan ranges. According to Blackwelder, this material indicates the occurrence of the Tai-shan complex and one or more pre-Cambrian sedimentary series. About 5 miles west of Wen-shui-hsien there are hills of rounded contour. In these hills Obrutchov mentions the occurrence of gneiss and granite which lie beneath the Cambrian.[68]

On the lower slope of the Ho-shan range which borders the eastern margin of the Fen-ho valley, Blackwelder observed, from a distance of 10 miles, an exposure that appears to be of dark metamorphic rocks with steep inclination and without notable difference of hardness. He infers[165] that these rocks are probably the basal complex and other associated pre-Cambrian formations. As a check of his distant observations, pebbles brought down by streams from the range are found to consist of quartzite, grey limestone, grey gneiss, pink granite, diorite etc. The grey limestone was identified to be the Sinisian limestone which overlies the pre-Sinisian group elsewhere. Richthofen also maps the same area as gneiss and schists.

From the Fong-hwang-shan range, Richthofen reports[84] gneiss and crystalline schists overlain by reddish quartz-sandstone. The limited observations made by Willis and Blackwelder confirm this report.

Gneisses and granites showing the characteristics of the basal complex are reported to occur in the Ta-hua-shan range.

N.W.China.

The Nan-shan region.

On the south of the To-lai-shan Obrutchov observed a zone of highly inclined gneiss which is unconformably overlain by "upper carboniferous". On the southern side of this narrow zone almost flat beds of the "Angara series" and the "Gobi series" are exposed. These two series are of considerably younger age than the gneiss, as will be described later.

Near the valley between the Alexander III range and the To-lai-shan, which leads to the Da-kou pass, (3380 m) Obrutchov observed biotite-gneiss striking N.W. and dipping 60° to 70° N.E.

Between the Da-bej-che and the To-lai-che, on the southern side of the To-lai-shan, a zone of gneiss was observed by Obrutchov, The rocks consist of hornblende-schist with highly inclined beds of crystalline limestone. This zone not only extends far to the west, but rises to the height of Chyj-daban. Southward these rocks are overlain by "Carboniferous strata".

The Da-ssue-shan is formed by rocks of large variety, and very ancient type: Quartzite, hornblende schist and spotted slates (Fleckschiefer) are accompanied by porphyry, granite and diabase. Similar rocks are found in the Ye-ma-shan, the next range to the south of the Da-ssue-shan. The strata strikes N.E.

The Humbolt mountain is largely formed by highly inclined crystalline schists which are uncomformably overlain by ? mesozoic. "Ueberkohlen Sandstein". The latter is much less metamorphosed.

A large part of the Ritter mountain is occupied by highly quartzitic metamorphosed phyllites. (Tonschiefer). On the southern slope of the Zagan-tscholu hornblende granite and porphyries were noted by Obrutchov. Schists also occur, which assume a general northwesterly strike.

In the Muschketow range, gneiss, crystalline schists, quartzite and limestones are the prevailing rocks.[19]

Along the northern slope of the Nan-shan range, Loczy distinguished a formation which he calls "Nan-shan sandstone".[51] It consists chiefly of grey-green sandstones and clay slates, which are frequently traversed by distinct cleavage or schistosity and which are barren of fossils except for the occasional indistinct impressions, that may possibly be ascribed to fucoids. This formation is apparently intimately folded and is intruded by large masses of granite. Loczy tentatively refers the Nan-shan sa sandstone to the Wu-tai formation of Richthofen.

Kan-su.

In the western part of the Lo-pan-shan, near Ping-lean-fu, Loczy observed chlorite-schist rising above the mantle of loess.

To the S.E. of the town of Lan-chou, gneissic rock crops out in a rocky gorge cut by the Yellow River. The gneiss strikes E 30 N.[143]

Between Min-chou and Kiu-tien, Futterer observed a mound composed of coarse-grained quartzite and slates (Schiefer) rising above the loess plain. These strata strike W.S.W.-E.N.E. and are referred to the Wu-tai formation by Futterer.[25]

At Hsia-kou-yi, half way between Kan-tschou-fu and Lang-tschou-fu, Futterer saw green slaty rock striking N. 15° W. and dipping 80° E, which he assigns to Wu-tai formation. The same rock crops out on the west of the coal field, south of Hsia-kou-yi.[25]

Near the town of Ku-lang-hsien, Futterer observed grey slates (schiefer) which he identified as the "Nan-shan sandstone", and regards it as the Wu-tai formation. Above Wu-schöng-pu, North of Ping-fan-hsien, green rocks, graywacke, quartzite and unfossilifrous limestone occur; these form a lofty precipitous mountain covered by red and grey-green sandstone.

Central China.

The Tsing-ling Range.

Eastern Tsing-ling-shan. On the southern ridge of the Fu-niu-shan, the Kiu-li-shan, Ho-nan, Richthofen saw chloritic schist and crystalline limestone; and highly folded strata of grey-green slates (Ton-schiefer) and slaty quartzite. They are unconformably overlain by coarse conglomerate and sandstone with coal seams.[85] In the northern part of the Fu-niu-shan, crystalline limestone, crystalline schists, gneiss and a large mass of granite occur. The granite gives off dykes and quartz-veins cutting across the gneiss. The crystalline schists are intruded by quartz-porphyry. Richthofen maps the whole of these rocks in this region as "gneiss and crystalline schists in general" and regards them as Archean.

Between long. 112° and 109°E Loczy[52] crossed a broad belt of monotonous biotite schist; in association with the schist, there occur dark amphibole-schists, chlorite gneiss, gneiss and lenses of white granular limestone. These metamorphosed sediments are intruded by massive diorite, coarse grained amphibole granite and pegmatite which locally changes the schists to hard, fine-grained gneisses This complex is classed by Loczy under the "Azoic" or Archean formation. To the north of this broad belt of the biotite schist lies the main range of the eastern Tsing-ling which, according to Loczy, consists of gneiss-granite, gneiss, amphibole-schist, mica-schist, phyllites and crystalline limestone, intruded by massive coarse-grained granite.

Central Tsing-ling-shan. In long. 108° 30' E, between Chou-chi-hsien and Liu-yue-ho, Shen-si, Willis and Blackwelder[166] observed a broad zone of green schists, prevailingly chloritic, in which occur thin beds of quartzite and highly siliceous marble. South of Liu-yue-ho, the green schists are succeeded by White quartzite and massive grey limestone folded in a syncline. The cont-

contact between the green schists and the limestone and quartzite was not observed by Willis and Blackwelder; but they remark that the green schists bear strong resemblance to the chlorite-schist occurring in the Wu-tai-shan, north eastern China.

Western Tsing-ling-shan. During the journey from Pau-ki-hsien to Pai-shi-pu, Richthofen[86] first observed an extensive mass of granite with which occur mica-gneiss, hornblende and Chlorite-gneiss and other highly altered rocks. The gneisses are everywhere penetrated by the granite. To the south of the Twi-tsze-shan, the gneiss and granite are succeeded by a green rock containing abundant hornblende and chlorite, and is intruded by dykes of granite, pegmatite and quartz. These rocks are soon replaced towards the south by the typical chlorite-schist occurring in the Wu-tai-shan. Further south the schist is succeeded by ? "Silurian limestone"

Between Lo-jan-shien (Lio-yang-hsien) and Tschau-tjeu in long.106° 20' between lat.32° 30' and 33° 30'N Loczy[53] observed crystalline schists, gneiss and phyllite, and crystalline limestone. He classes these rocks under "Archean", and distinguishes them from the overlying altered palaeozoics.

The Middle Yang-tze District.

Above the I-chang gorge, western Hupeh, in a denuded broad anticli ~~exposes~~ an inlier of granite, the Hwang-ling granite, ~~which~~ is exposed. The granite is intersected by dykes of granite, diorite, and veins of aplite, and rocks which belong to the lamprophyre group. Flanking the granite core, Abendanon distinguishes a series of "metamorphic schist" consisting of hornblende, chlorite and mica with alternating layers of nearly pure quartz. Pumpelly[73] mentions the similar schist with quartz veins. Thus the two observers agree. But Willis and Blackwelder state that they have not seen any altered sediments, in situ, in between the Hwang-ling granite and the overlying Sinisian formation. In all probability, the schists observed by Abendanon and Pumpelly are absent at the localities where Willis and Blackwelder made their observations.

The Han Valley.

In summing up the observations made in the valley of the Han-kiang, Richthofen distinguishes a group of gneiss which according to the same author, is probably older than the "old palaeozoic group" of hard quartzite, and folded and over-turned schistose limestone with slates and phyllites. The gneiss is exposed near Li-Ho-kou forming mountain chains which have a S W - N E trend.[103]

Northern An-hwei and Eastern Hupeh.

Gneiss and schists apparently of highly complex character occupy large area in northern An-hwei and eastern Hupeh, in the districts of Kwang-ji-hsien, Hwang-mei-hsien, Tai-hu-hsien, Chien-shan-hsien, Sou-sung-hsien, Yin-shan-hsien etc.[190]

Western China.

The occurrence of "Archean" rocks in the high mountain ranges between Batang and Ta-tsien-lu has been described by Loczy.[54] They consist of (a) gneiss and crystalline schists intruded by granite, syenite, diorite and other igneous rocks; (b) monotonously clayey sandstone, of grey and dark colours, associated with clay schists and also with amphibolite and chlorite-schist. Semicrystalline limestones occur beneath the sandstones. The strata are extensively intruded by granite.

S.W.China.

Leclere[40] mentions a group of ancient rocks, occurring in the central part of Kwang-si; they are frequently exposed on the banks of the rivers between Kwei-lin-fu and the Si-kiang. The upper part of the formation is composed of highly indurated quartzite with black and white bands. On the west of Hoai-Iuen, the same formation consists of uniform quartzose phyllite with greenish grits and a little mica. This whole series attains a thickness of about 600 m in the said locality. Leclere refers this formation to the "pre-Cambrian system" and he states that good exposure of this "pre-cambriam" formation is to be found on the west of the Kien-kiang; in the vicinity of Ta-li-fu; and in the zone of the "Hou-kouang fracture," between Kwei-chow and Kwang-si.

Southern China.

Kingsmill[35] describes a belt of "quartz rock" alternating with beds of slates and quartz. These sedimentary rocks are entangled in the granite, and run across the isle of Hong-kong, in a W.N.W.-E.S.E. direction. The complex nature of the so-called quartz-rock is best explained in Kingsmill's own words: "In some place the rock might be mistaken for an igneous formation and in others it approaches conglomerate, * * * * It would be difficult to obtain two specimens alike" This rock is overlain by the prevailing red sandstone.

III SUMMARY.

Classification and correlation.

Three systems of the pre-Sinisian rocks in the Wu-tai district have been tentatively established by Willis and Blackwelder as already described. (see pp55-69). There is little doubt as to the absolutely basal position of the Tai-shan complex, as defined by the same geologists, for its thickness everywhere extends downwards to indeterminable depth. But as to the establishment of the other two systems, the Wu-tai and the Hu-to systems, Willis and Blackwelder themselves consider the observed facts to be insufficiant to warrant a definite conclusion. It is therefore necessary, apart from lithological and structural reasons, to distinguish the Tai-shan complex or the fundamental complex from the Wu-tai and the Hu-to rocks. Thus we recognize two groups of pre-Sinisian rocks in China:

B. Upper. Wu-tai and Hu-to formations.

A. Lower. Tai-shan complex or fundamental complex.

A. Lower pre-Sinisian.

The Fundamental Complex.

This basal mass of rocks in China, as in many other parts of the world, is readily identified by its peculiar lithology and structure. In the Wu-tai district, Shan-si, it occures below the upper pre-Sinisian group. In the Tai-shan district, Shan-tung, the fundamental complex is overlain by the lowest Sinisian stratum or the lowest Cambrian formation. Both in Shan-si and Shan-tung, the complex contains calcareous and micaceous material, which according to Blackwelder is probably of sedimentary origin. Granting that such material is true sediment, the writer proposes to call the period during which the sediment was formed, the eo-proterozoic period. Since the fundamental complex is largely composed of igneous intrusions, the greater part of it was presumably formed in past eo-proterozoic time.

According to Richthofen, ~~and~~ Willis and Blackwelder, gneiss and schists of the fundamental group are extensively developed in Shan-tung; but Rinne[134] and Lorenz have ~~independently~~ stated that they saw very little true gneiss during their journey in the same province. In their opinion the so-called Archean gneiss spreading far and wide in that province, and being overlain by palaeozoic sediments, is nothing but granular micaceous granite of "Algonkian" age.

Judging from the lithological and structural peculiarities, we may regard the following rocks as belonging to the fundamental complex.

1. The Tai-shan complex occurring in N.E.China as identified by Willis and Blackwelder.
2. The gneiss and granite observed and described by Richthofen in the western Tsing-ling-shan.

The other gneiss and schists described under the heading of field observations (pp 78, 79, 82, 83.) are only tentatively referred to this group. Without further evidence the writer is unable to attempt definite correlation.

B. Upper pre-Sinisian.

Wu-tai System (Meso-proterozioc.)

In the Wu-tai district, S.E of Shi-tsui, the Tai-shan complex is overlain by mica schist and schistose quartzite. (see section No. 5) Whether the mica schist and quartzite are altered sediments or mylonized products due to shearing between the Wu-tai rocks and the Tai-shan complex or in other words, whether the junction is a thrust or a natural one is an open question. ~~for Bailey Willis does not raise.~~ Apart from the nature of this junction, however, the bedded character of the quartzite and its overlying strata as compared with the chaotic features of the Tai-shan complex is positive evidence that the two are unconformable. Since the Wu-tai series overlies the Tai-shan complex, and the former is plainly a metamorphic sedimentary series, it is natural to regard the Tai-shan complex as underlying the Wu-tai system.

It is true that the lithology of the Wu-tai rocks as exposed on the southeastern flank of the Wu-tai-shan, naturally invites us to classify them into three series, as Willis and Blackwelder do, the lowest Shi-tsui series being most quartzitic and micaceous, the middle Nan-tai series calcareous and quartzitic the upper Si-tai series most uniformly chloritic. This classification is strengthened to some extent by the presence of conglomeratic layers at the base of the Si-tai series. The conglomerate can be regarded as basal conglomerate, indicating marked unconformity, provided that no evidence of their being crush conglomerate can be brought forward. The existence of thrust planes and of intrusive masses of igneous rocks in the sections observed by Willis and Blackwelder along the southeastern flank of the Wu-tai-shan make the relative position of the three series obscure. To solve this problem we may argue in the following way:

The Shi-tsui series is in direct contact with the Tai-shan complex. The arkose bed at the bottom of the series consists of material of such a type as would be furnished by the Tai-shan complex exposed in the eastern mountains of the same district. Moreover, the sediments are principally coarse material, suggesting the incipient transgression of the Wu-tai sea. For these reasons we have some confidence in regarding the Shi-tsui series as the lowest of the three. In the Si-tai series the sediments vary upwards from the coarsest conglomerate gradually to fine chlorite-schist. Here we have strong evidence to show the gradual deepening of the Si-tai sea. What lies underneath the Si-tai series might, then, be an elevated and eroded land surface. Therefore in the absence of a thrust immediately underneath this conglomerate we know that the Si-tai series is at least, younger than the members lying immediately underneath the conglomerate. Our next procedure is to find a proper place for the Nan-tai series. On account of the calcareous nature of the Nantai series, it has been suggested by Willis and Blackwelder that it might be a deep sea facies of the Shi-tsui series, being brought to its present position by thrust. According to this idea the Wu-tai system can only be divided into two series. On the other hand, it is equally possible that the apparent position of the Nan-tai series is also its real position. In this case, there must be a period intervening between the Shi-tsui and the Si-tai of such a length as to yield the rocks of the Nan-tai series. Richthofen made observation between Che-foo and Teng-chou-fi, eastern Shan-tung, where mica schist is overlain by a series of alternating crystalline limestone and schist with quartzite. The limestone becomes more important as the sequence is followed upwards. the total thickness of the same series amounts to several thousand feet. Willis compares Richthofen's case with his Wu-tai sections. If the lower beds of Richthofen's section near Che-foo are eventually proved to be equivalent to the lower series of the Wu-tai system in the Wu-tai district, then there would be a similar lithological succession of the upper pre-Sinisian group in N.E.China and the calcareous Nan-tai series would be probably younger than the Shi-tsui and older than the Si-tai series,.

Hu-to system (neo-proterozioc)

The nature of the unconformity between the Hu-to system and those below has been described in connection with the occurrence of Hu-to rocks in the Wu-tai district. According to Willis and Blackwelder it is decidedly younger than the Wu-tai system and the Tai-shan complex. The lower Hu-to series is mainly argillacous, while the upper Hu-to series is essentially calcareous. This classification is borne out by the interpretation of the structure of the Hu-to rocks occurring in the vicinity of the Wu-tai-shan. The structure is believed, by Willis, to be a large synclinorium with its axis pitching S.W. If the calcareous series is the upper division and argillaceous the lower, we should expect that the calcareous series of the Hu-to system are chiefly exposed in the central region of the synclinorium and the argillaceous series in the margin of the synclinorium i.e. towards the N.E. and S.E. end of the entire expanse of the exposure in the district cited. The observed facts agree with this view.

The Ta-yang limestone of Willis and Blackwelder is always reported to rest upon an eroded surface of the Tai-shan complex. In one case it is overlain by a series of conglomerate, quartzite, shale, etc. It is unfossiliferous for all we know; it differs from these Sinisian limestone in many respects; and it certainly cannot be a later formation than the Sinisian. Richthofen at the Nan-kou pass, N.E. of Peking, noted whitish-grey crystalline limestone with rows of black flints extending downwards to an unknown depth. Similar limestone came under his notice in Hsi-ping-shan, south of Chi-li. There the flinty limestone rests on grey crystalline limestone. These limestones together with the Ta-yang limestone and the Tung-yu limestone of Willis and Blackwelder may all belong to the upper calcareous division of the Hu-to system as suggested by Willis. But it is equally possible that the Ta-yang limestone, the Nan-kou limestone, and the Hsi-ping-shan limestone are younger than the Tung-yu limestone. The highly eroded surface of the Tung-yu limestone in the Tung-yu district accounts for the total disappearance of the Ta-yang limestone if ever existed.

As stated above the Tung-yu limestone is seen at many localities resting at once on the eroded surface of the Tai-shan complex. If th the Ta-yang limestone is the latest developement of the Hu-to period, this fact would indicate that the slowly expanding

Hu-to sea finally transgressed the higher Hu-to land which had been denuded to a peneplain. This view gains weight when we come to consider the gradual increase of calcareous material in place of arenceous and argillaceous deposits throughout the entire succession of the Hu-to rocks from its base upwards.

Having thus provisionally established the sequence of the upper pre-Sinisian formations in the Wu-tai district which may be taken as a type-area, and correlated the more important equivalents in N.E.China, we may proceed to enumerate the formations which are most likely to belong to the same group.

After studying Richthofen's China vol. II, Loczy correlates his Nan-shan sandstone (p 80) with Richthofen's Wu-tai series, viz. the Wu-tai system of Willis.

Both Richthofen and Willis emphasize the lithological similarity between the chlorite-schist of the Wu-tai-shan and that of the Tsing-ling-shan. In the western Tsing-ling-shan the schist occurs in association with the fundamental gneiss and granite; in the central Tsing-ling-shan it lies near a belt of white quartzite and massive gray limestone. The same authors agree in regarding the chlorite schist of the Tsing-ling-shan as partly equivalent to the Wu-tai formation in the Wu-tai district.

The broad belt of mica schist in the eastern Tsing-ling, (p 81) and the "Archean Zone" between Lio-yang-hsien and Tschau-tjen in the western Tsing-ling, (p 82) may be tentatively referred in the opinion of the writer, to the upper pre-Sinisian group. This view is based on the fact that the lithology of these rocks resembles, to a degree, that of the Wu-tai rocks exposed in the Wu-tai district.

The Hwang-ling granite (p 82) exposed in the gorge district of the middle Yang-tze, is regarded by Willis as an Algonkian intrusion. His assignment of pre-Cambrian age to this granite is strengthened by the fact that the Cambrian or Sinisian strata overlying the granite is in no way effected by this large intrusive mass. The schist (p 83) observed by Pumpelly and Abendanon in the same district is in all probability altered pre-Sinisian sediment.

The clayey sandstone formation with amphibole and chlorite-schist occurring between Batang and Ta-tsen-lu (p 83) is referred to the Wu-tai formation by Loczy. The presence of the chlorite-schist is the basis on which he makes his correlation.

The inadequate data do not enable the writer to assign a definite stratigraphical position to the highly altered sedimentary rocks observed by Obrutchov in the Nan-shan region (p 78); but he suggests that they possibly belong to the upper pre-Sinisian.

The reason that Futterer correlates the quartzite and slates exposed near Min-chou, Kan-su, (p 80) is not clearly stated in his original work "Durch Asien". Presumably, he does so on account of the lithological similarity between these rocks and a certain phase of the Wu-tai series as described by Richthofen.

Leclere definitely mentions outcrops of pre-Cambrian formations in S.W.China. If the quartzite (p 84) that he classes as "pre-Cambrian" system is true pre-Cambrian formation, it may be tentatively regarded as belonging to the upper pre-Sinisian group, for the lithology of the rock suggests certain similarity to that of the Wu-tai strata.

The Kauling formation which is extensively exposed in Kiangsi, (see p 134) was originally classified by Richthofen as Cambrian, but Tiessen, the editor of "China" vol. III. suggests that it may possibly belong to the pre-Cambrian group. In the opinion of the writer the Kauling formation is more likely to be a Cambrian formation; accordingly, it is described under the Sinisian system.

It is hardly necessary to say that all these tentative correlations are open to criticism, and the known data are too few to arouse vigorous arguments.

The age of the Pre-Sinisian formations.

The absolutely basal position and the peculiar structural and lithological type of the Tai-shan complex, the lower pre-Sinisian group, remind us at once of the Lewisian in Britain and the fundamental complex in North America. Their equivalency seems to be self-evident, and needs no further argument.

As to the upper pre-Sinisian group, Richthofen and Willis often speak of its Huronian or Algonkian age. It is true that the general composition and to some extent the structure of the Wu-tai rocks are comparable with those of the Huronian formation in North America, but a distant correlation based on lithological ground does not seem to be a sound one. Either direct or indirect fossil evidence is demanded. Owing to the generally unfossiliferous nature of these rocks it has been impossible to obtain organic remains of stratigraphical importance in the pre-Sinisian in China, and the pre-Cambrian in Europe and North America. On the other hand, abundant forms of life, particularly trilobites, are recorded near in the base of the Sinisian in China and the Cambrian in Europe and North America. If we can prove that the base of the Sinisian is equivalent to the base of the Cambrian, it would follow that the pre-Sinisian in China is of pre-Cambrian age.

Walcott has shown that the Chinese lower Sinisian sea was connected with the Australian lower Cambrian sea by the presence of the common genus Redlichia; and the middle Cambrian sea of China was obviously in communication with that of Western America and Europe by the presence of a large number of related forms. Thus it is beyond doubt that the base of the Sinisian can be regarded as the base of the Cambrian for all practical purposes.

In N.E.China, the base of the Sinisian system consists of a red shaly formation, the Man-to shale of Willis and Blackwelder, (see p 102) containing Redlichia and other lower Cambrian forms. This red shaly rock is described by Richthofen in his Nan-kou section (p 111 +71) and Hsi-ping-shan section (p 69). The flinty limestone lying beneath this red shaly rock, (Man-to shale) is correlated with the Ta-yang limestone which is regarded by Willis as the upper part of the Hu-to system.

In Northern Shan-si near the Wu-tai district, Blackwelder observed that eroded and weathered Tai-shan complex, Wu-tai schists and Hu-to limestone are in a number of instances unconformably overlain by the red shaly formation with local conglomerates. For these reasons we may consider it as conclusive that the pre-Sinisian groups in China are of pre-Cambrian age.

C A M B R I A N - M I D D L E   O R D O V I C I A N . . .

or

The Sinisian System.

- - - - -

(1) General Remarks.

The term "Sinian"[74] was first introduced by Pumpelly for expressing a system of folds trending N.E.- S.W, observed by him throughout N.E. Asia. Richthofen during his exploration found a group of ancient rocks spreading over large areas in China, and being generally affected by the N.E.- S.W. folds. He then called this group of rocks "Sinisch"[27] which was later anglicized by A. Geikie as "Sinisian". Richthofen ~~remarks~~ believes that the formations belonging to his upper Sinisian or "Obersinisch" probably extend stratigraphically above the Cambrian, and his lower Sinisian or "Untersinisch" possibly reaches down to the pre-Cambrian.

In the years 1903-4 Willis and Blackwelder discovered an unconformity of great magnitude between the Obersinisch and the Untersinisch of Richthofen in northern Shan-si; and they call this unconformity the "pre-Sinisian Unconformity". Moreover they noted that the Untersinisch is generally unfossiliferous, while near the bottom of the Obersinisch, a number of species and abundance of individuals have been found. In the districts between northern Shan-si and S.W.Chi-li, Blackwelder observed thirteen instances of Sinisian beds (=Obersinisch) lying in contact with the pre-Sinisian formations. Nine cases out of the thirteen, the same geologist was able to observe erosion unconformity; the underlying pre-Sinisian is often traversed by dykes which terminate abruptly at the plane of the umconformity. The other cases are fault or thrust junctions. Blackwelder and Willis therefore found it desirable to restrict the lower extension of the "Sinisch system" as established by Richthofen. For denoting the "Sinisch" system in this restricted sense, they adopt the old nomenclature "Sinian", the plane of the "pre-Sinian unconformity" being regarded as the lower boundary of the "Sinian system".

To avoid confusion, and to do justice to Pumpelly's early discovery, the writer thinks it more appropriate to use the term "Sinian" in its original sense as defined by Pumpelly, (see p33o) i.e., to denote the prevailing N.E - S.W trend of the major folds in N.E. and S.E.China; and to use the phrase "Sinisian system" in lieu of the phrase "Sinian System" as defined by Willis and Blackwelder.

Although the Sinisian rocks are widely distributed in northern, S.W., S.E., and probably western China, the Sinisian formation, as a system, appears to be most well-defined in N.E. China,. The grand developement of the almost undisturbed Sinisian strata in Western Shan-tung, and their magnificient exposures with abundant fossils, have induced a number of geologists and palaeontologists to concentrate their attention to that area. A tolerable fauna has been collected from Shan-tung, and described by Dr Walcott. The labour spent by Dr. Deprat on the Cambrian formation in S.W.China is also a fruitful one; but there the severe deformation suffered by the Cambrian strata has rendered the region less favourable than Shan-tung for studying faunal sequence. The work of Richthofen on the Sinisian formation in S.E.China, valuable as it is, gives us little satisfaction as regards the record of organic remains.

The lower member of the Sinisian system in N.E.China usually overlies the Tai-shan complex or the Wu-tai formation or the Hu-to rocks with marked unconformity; but in one or two known cases the unconformity does not seem to exist. Richthofen's section at the Nan-kou pass affords such an example. (see p 71) The upper limit of the Sinisian system in N.E.China is marked by an unconformity of such a nature as to represent a great hiatus of the succession of life; and to exhibit visible trace of erosion and notable change of lithology between the upper Sinisian rocks and the rocks belonging to the overlying ~~Sinisian~~ Shansian system. (see p 163) But, there is a wide concordance of stratification between the uppermost Sinisian bed and the lowest Shansian stratum. It is uncertain whether the corresponding break defining the upper boundary of the Sinisian system exists in the other parts of the country. If it does exist, it need~~s~~ not ~~to~~ be at the same horizon, for the upper part of the Sinisian system in northern China had been presumably eroded off before the deposition of the overlying Shansian base had begun.

In eastern Yun-nan, Deprat has shown that, at a certain locality, a number of upper Cambrian beds are missing underneath the Ordovician; and the Ordovician passes upwards into the Silurian in a conformable manner. If this break between the Ordovician and the Cambrian is proved to be a mere local non-sequence, or due to tectonic movement in post Ordovician time as suggested by Deprat, (if the writer understands him rightly) it may be possible to extend the use of the term Sinisian to S.W. China, but if it is an unconformity of appreciable magnitude, the application of the Sinisian system in Eastern Yun-nan would be thoroughly unsuitable. In the absence of further data concerning the nature and the extent of the alleged unconformity between the Ordovician and the upper Cambrian in Eastern Yun-nan, Deprat's suggestion is tentatively regarded as a valid one.

With regard to the ~~boundaries~~ age of the Sinisian system, we have convincing evidence to show that the lowest bed of the same system in Northern China is practically equivalent to the Cambrian base; and from the uppermost stratum of the system, forms related to the Trenton fauna of North America have been found. Thus it is certain that the Sinisian system in China, at all events in northern and central China, covers a period which extends from the lowest Cambrian at least to the middle Ordovician.

The nature of the rocks belonging to the Sinisian system shows a tendency of changing from (the lower) shallow water deposits to (the upper) deep sea sediments. The change is gradual but unmistakable indicating the slow and continual subsidence of the sea floor during the Cambro-Ordovician time throughout China.

There is a general absence of basal conglomerate in the Sinisian system over an extensive area except at a few localities in Northern Shan-si and Western Chi-li where the developement of the conglomerate is strictly local. Instead of the usual presence of a conglomeratic band above a plane of great unconformity, we find deposits which are presumably derived from laterite in Northern China, and a consolidated glacial formation or tillite in Central China. They form the base of the Sinisian system. The discovery of glacial deposits in early Cambrian time in Central China is entirely due to the energetic research and astute observation of Dr. Willis and Mr. Blackwelder. It is much to be regretted that their hurried journey did not allow them to obtain any more data than one locality of the exposure of the tillite and its approximate stratigraphical position.

Fossils that have been found in the Sinisian system. are mainly trilobites and brachiopods; gastropods, cephalopods, ostracods etc are also fairly well represented. The lower Sinisian fauna is characterized by the species, Helcionella rugosa chinensis, Obolella asiatica, Redlichia chinensis and certain species of Ptychoparia. The middle Sinisian has yielded a large number of species and individuals. Dorypyge richthofeni, Agnostus, Anomocare, Solenopleura, certain species of Ptychoparia, Stephanocare, Drepanura, Obolus, Orthotheca etc, are among the characteristic forms. The upper Sinisian is usually not so fossiliferous as the middle and lower Sinisian; but the genus Asaphus Dionide, large orthoeras or "pagoda stone", etc, occurs near the top of the system.

(II) Field Observations.

(Under this heading fossils are mentioned by reference No. Their generic and specific names are found in list No. 1.)

N.E.China.

Western Shan-tung.

The lithological as well as faunal succession of the Sinisian formations in Western Shan-tung has been elaborately worked out by Messrs. Willis and Blackwelder. Although the area that they covered during their exploration in Shan-tung is limited, the Sinisian formations in N.E.China appear to be well represented in that area, as proved by the more extensive observation made by Richthofen. For this reason we may take Western Shan-tung as a type-area showing the full developement of the Sinisian formations in N.E.China.

In Western Shan-tung, the Sinisian formations are divisible into three series according to Willis and Blackwelder:

Upper (c)	Tsi-nan limestone	massive limestone.
Middle (b)	Kiu-lung group	limestone and shale.
Lower (a)	Man-to formation	essentially shale.

The sequence of these three series is not inferred but is actually observed. Therefore there is no question about their succession; and we may consider the above order as an established fact.

(a) Man-to formation.

Blackwelder describes the Man-to formation[167] as being primarily a series of red and brown shales with interbedded gray and buff limestones, which are usually of earthy composition.

Good exposures of the Man-to formation were noted by Blackwelder in the slopes below the cliffs on all sides of the village of Chang-hia, in the hills northeast of Sin-tai-hsien, in those between Kau-kia-pu and Yen-chuang, and 19 to 24 kilometers south of Po-shan. The total thickness, according to the same author, ranges from 135 to 225 meters.

On the slope of the Man-to-shan, south of Chang-hia, the complete Man-to formation is exposed. The sequence is as follows: (see section No. 18)

Kiu-lung group.	5. Thin.bedded dark oolite and greenish shale.
Man-to formation with (Redlichia chinensis)	4. Brown and gray shale with two intercalated thin layers of gray limestone and a layer of gray limestone lying at the base. This basal layer contains Se19, Si 32 to Si 35.
	3. Dark shale with a layer of olive-gray limestone lying at the base. The latter contains Se 30, Si 42, Si 32
	2. Red shale with basal white calcareous shale and buff earthy lime. The buff limestone yields Si 42, Si 37.
	1. Shales with a band of buff earthy limestone near the base, a sill of syenite porphyry in the middle and a layer of slaty black limestone which yields Redlichia chineusis, (Si 7) in the upper part of the series.
(Unconformity)	————————————
Tai-shan Complex.	

[illegible]

In the Sin-tai district, the succession of the Man-to formation is essentially the same as that in the Chang-hia district. In the slopes of the Hu-lu-shan, south of Yen-chuang and the Hwang-yang-shan, east of the Hu-lu-shan, Se 30, Sf 11, Sg 3, Si 43, Si 9 have been found ~~from~~ in the Man-to formation.

(b) Kiu-lung group.

The Kiu-lung group largely consists of limestones with a subordinate number of shaly strata. The limestone is often oolitic and pseudo-conglomeratic. The horizontal extension of each member of this group is not so persistent as the members of the underlying Man-to formation. Blackwelder says that a thick hard limestone belonging to the Kiu-lung formation sometimes grades off into shales within a few miles. The Kiu-lung group is conformably underlain by the Man-to formation, and conformably overlain by the Tsi-nan limestone to be described presently. The total thickness varies from 275 m to 335 m.

The rocks belonging to the Kiu-lung group are exposed in the hills near the villages of Chau-mi-tien and Chang-hia, in the low pagoda hill near Tai-an-fu, in the hills 16 Kilometers southeast of the same city, in the mountains of the Sin-tai --- Yen-chuang district and those lying about 16 Kilometers south of Po-shan.

In the Chang-hia district, the Kiu-lung group is divisible into three conformable series:[169]

3. Chau-mi-tien limestone with Ptychaspis, Tsinania and Plectorthis (see section 19) This limestone is conformably overlain by the yellowish dolomitic Tsi-nan limestone. The transition between the

Chau-mi-tien limestone and the Tsi-nan limestone is marked by a notable lithological change. The upper part of the Chau-mi-tien limestone consists of hard gray finely crystalline limestone with individual strata which are usually not more than 5 or 6 feet thick, and yields fossils Se 29, Se 36, Se 33, Sf 7, Sg 6, Si 108, Si 118, Si 155. The lower part of the limestone is thinly bedded and sometimes exceedingly hard. It contains fossils Si,1, Si 163, Si 164, Si 81, Si 78, Si 79, Si 152, Si 118, Si 113, Si 114, Si 105, Si 111, etc. In the base of the Chau-mi-tien limestone there is a stratum of dense slabby limestone containing peculiar pseudo-conglomerate which consists of a Olive-gray matrix and flattish, ellipsoidal or reniform pebble-like bodies rarely exceed 1 inch in diameter. This slabby limestone yields Si 94.

2. Ku-shan shale.
This is a calcareous shale of light green colour with seams of dense limestone, destitute of fossil, about 50 feet in thickness.

1. Chang-hia limestone (with Dorypyge richthofeni, Anomocare daulis, etc.) The upper part of the Chang-hia formation is composed of somewhat variable succession of dark and gray limestones which are occasionally oolitic: the middle part consists of massive, cliff-making beds of black oolite with grains of glauconite; the lowest strata are composed of thin-bedded olive-gray limestones which are in part oolite. Abundant middle Cambrian fossils have been found from various horizons of this formation. They are arranged in descending order as follows:-
Se 24, Sg 1, Si 120, Si 145, Si 86, Si 29, Si 156, Si 158, Si 15, Si 85, Si 103, Si 149, Si 148, Si 98, Si 99, Si 89, Si 84, Si 51, Si 52, Si 63, Si 107,

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Sf 10, Si 84, Si 102.

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Sf 1, Sf 6, Sf 12, Si 51, Si 100.

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Sf 12, Si 51.

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Si 84, Si 88, Si 106, Si 104, Si 92,
Si 101, Si 89, Si 6.

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Si 72, Si 15, Si 52.

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Se 23?, Sg 8, Si 69, Si 144, Si 44,
Si 45.

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Se 31, Si 147, Si 68, Si 146.

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In the Sin-tai district, the three divisions of the Kiu-lung group still hold; but here the thickness of the black oolite is much reduced, being replaced by shales. The Ku-shan shale is thicker than it is in the Chang-hia district, and it carries fossils which belong to the upper part of the Chang-hia limestone and lower part of the Chau-mi-tien limestone of the Chang-hia district. The Chau-mi-tien limestone is essentially the same as in the Chang-hia district.

Near Yen-chung, north of Sin-tai-hsien, Blackwelder describes a section of the Kiu-lung group as follows:-[170]

5. "uppermost limestone member" . . . . .250 to 300 ft.
"(Thin-bedded gray limestones, often
conglomeratic, which represents most of
the Chau-mi-tien formation)"
with the following fossils,
Sh 2.

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Se 32, Se 35, Se 33, Se 39, Sg 2, Sg 6,
Si 151, Si 109, Si 112, Si 115, Si 116,
Si 118, Si 94, Si 90.

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Si 27.

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Si 97, Si 94, Si 134.

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Se 29, Si 57, Si 94, Si 55.

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4. "upper shale member" . . . . 100 to 120 fet.
"(Green shales, usually in two layers separated by a thin limestone. The shales themselves are sometimes soft and argillaceous, but at other levels are hard and slaty, containing numerous limestone nodules)"
with the following fossils.
Se 22, Se 18, Se 12, Si 1, Si 3, Si 21,
Si 22, Si 25, Si 31, Si 30, Si 41,
Si 146, Si 54, Si 8, Si 10, Si 58, Si 24.

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3. "Middle limestone member" . . . . 120 to 150 ft.
"(Light gray dense or granular limestone, usually mottled with ocher. Represents the upper one-third of the Chang-hia limestone)"
with the following fossils.
Se 25, Si 60, Si 83, Si 27, Si 26,
Si 23, Si 17, Si 19, Si 149, Si 56.

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Se 26, Se 6, Sg 1, Si 137.

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2. "Lower shale member" . . . . 100 to 170 ft.
"(Soft green shales containing thin strata and nodules of dense limestone)"
with the following fossils.
Sc 1, Se 25, Se 9, Se 7, Se 12, Sf 6,
Sg 1, Sg 7, Si 1, Si 63, Si 82, Si 157,
Si 156, Si 15, Si 14, Si 123, Si 145,
Si 136, Si 153, Si 132, Si 137, Si 53.

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Sc 1, Se 25, Sf 6, Sg 1, Sg 9, Si 1,
Si 137, Si 84, Si 155, Si 156.

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Se 23, Sg 9, Si 1, Si 3, Si 119, Si 132,
Si 137, Si 156, Si 15.

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1. "Lowest limestone member" . . . . . . .100 to 180 ft.
"(Dark gray limestone, much of it oolite and thick-bedded. The basal layers are frequently slabby and more or less replaced by green shales and calcareous sandstone)"
with the following fossils.
Se 7, Se 16, Si 59, Si 71, Si 68,

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Se 2, Si 59, Si 154, Si 126,

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Si 70, Si 136, Si 123, Si 39.

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Sa 1, Se 5, Se 25, Si 63, Si 136.

In the vicinity of Tai-an-fu, limestone strata form the isolated hill with a small pagoda about 1 mile west of the city. From this pagoda hill Blackwelder collected the following fauna which proves conclusively that the limestone is the Chau-mi-tien limestone.

Se 8, Se 13, Se 36, Se 39, Sf 3, Sf 8, Sf 4,
Sg 13, Sh 1, Si 163, Si 165, Si 105, Si 78,
Si 80, Si 57, Si 118, Si 47, Si 46.

(C) Tsi-nan Limestone. 171

The Tsi-nan limestone is lithologically divisible into two parts. The lower light coloured argillaceous limestone and dolomite conformably overlies the Kiu-lung, and is itself overlain by the upper brown dolomitic uniform limestone. The upper brown dolomite almost represents nine-tenths of the whole Tsi-nan formation and it underlies the coal bearing series of much younger age. (see p 198). The Tsi-nan formation is widely distributed in Shan-tung. Its exposures in the south of Tsi-nan and in the hill ranges of N.W.Shan-tung are most prominent.

In the Chang-hia district, the lower part of the Tsi-nan formation is essentially calcareous with earthy and dolomitic material. The lower strata grade upwards insensibly into moderately thick.bedded brownish dolomite which weathers to a blue-gray colour. The rock is slightly deformed, and traversed by calcite-veins. Fossils are extremely rare.

In the Sin-tai district, the nature of the Tsi-nan limestone is essentially the same as in the Chang-hia district. Near Tsai-kia-chuang, the Tsi-nan limestone has yielded the following forms:

Se51, Sf 16, Sf 17, Sh 2, Si 191?.

Having reviewed the inportant work contributed by Blackwelder on the stratigraphy of the Sinisian formations in Western Shan-tung, we may proceed to gether a few scattered observations made by other geologists in the same province.

After extensive study of the Sinisian system in the Liau-tung province where the developement of the Sinisian rocks is much the same as in Shan-tung, Richthofen subdivide the same system into two major groups:

(1) The unfossiliferous "Untersinisch" is conformably overlain by (2) the fossiliferous "Obersinisch".[87] In the opinion of Richthofen the same subdivision of the "Sinisch" system holds in the province of Shan-tung. Lorenz also classify the "Sinisch" formations into an upper and a lower group. It is uncertain whether the boundary-plane between the Obersinisch and the untersinisch drawn by Lorenz and that drawn by Richthofen agree with each other. Presumably they are approximately in the same horizon.

"Untersinisch"

~~At~~ To the south of Liu-pu, in the Tai-shan mountain, Lorenz[62] observed that the Untersinisch consists of siliceous and calcareous dolomitic rocks. (Rauchwacken) Similar rocks occur at Tsi-nan-fu according to Richthofen.

To the south of Wei-hsien, the Untersinisch of Lorenz is composed of yellow sandstone in the lower parts which is succeeded upwards by red marl.

At Tschang-liu-tschang, the lowest bed of the untersinisch is a red, gray, sandy marl with sericitic scales. This is followed upwards by siliceous calcareous-shale (Kalkschiefer)

No fossils were found by Lorenz from the Untersinisch formation in Shan-tung.

"Obersinisch".

The Obersinisch of Richthofen and Lorenz is a thick series of strata consisting of dirty yellow sandy marl, shale, calcareous-shale (Kalkschiefer) and slabby limestone with beds of characteristic globulitic or oolitic limestone.[88] The similar globulitic or oolitic limestone was observed by Richthofen in the Liau-tung province; (Lung-mon series) and is also observed by Gottsche in Corea.[202] Toll remarks that the oolitic limestone of Cambrian age is widely distributed in N.E.Asia.[152]

(The following observations were made by Lorenz with regard to the Sinisian formation in Shan-tung:-)

To the south of Tsi-nan-fu Lorenz observed the following succession of the Sinisian rocks: (see section NO.22)

10. Coal-limestone (Kohlenkalk)

9. Ferruginous clay (Lehmdecke)

(Note ---- Obviously No. 9 does not belong to the sequence of the bedded rocks. It is probably superficial deposits of recent origin.)

8. Red limestone somewhat crystalline.

7. Bedded Black limestone.

6. Limestone "conglomerate".

5. Yellow limestone.

4. Globulitic limestone, in part marmorized.

3. Pure & sandy bright brown limestone.

2. Thick-bedded black or speckled limestone.

1. Fossiliferous shaly globulitic limestone.

In the hill south of Wang-tschwang, between Mong-yin-hsien and I-shui-hsien, Lorenz observed the following sequence and collected three lots of fossils:[62] (see section No. 21)

8. Limestone containing Si 98 Si 176 . . . . . 24 m.

7. Limestone with an interbedded sill, below the sill the limestone contains Si 28, Si '28' . . . . 68 m.

6. Slabby limestone . . . . 30 m.

5. Marl . . . . 7 m.

4. Green-gray massive limestone with a layer of green marl near the base. Just above the marly stratum the limestone yields Si 143, Si 156, Si 1, Si 4, Se 21. . . . . 59 m.

3. Dark green-gray massive limestone with Si 143, Si 156, Si 4. etc. . . . . 23 m.

2. Thin-bedded, sandy and micaceous limestone with sandy layers and bands of gray crystalline limestone (spatkalk) containing large oolites . . . . . 90 m.

1. Calcitic, ferruginous, brown-violet conglomerate . . . . 7 m.

In the limestone hill of Ho-shan, south of the Pu-tschi coal field, Lorenz collected a few fossils. They are: Si 189, Sf 15, Sg 5,

The limestone contains strata of shaly dolomitic-rock (Rauchwacke), and it is unconformably overlain by coal bearing series. (see section No.24) Lorenz regards the limestone as "lower Silurian".[62]

Chi-li.

Near the Nan-kou pass, N.W. of Peking, Richthofen noted the occurrence of the Sinisian formations consisting of the following sequence: of rocks:[89]

M. Evenly bedded limestone without chert, dark gray to blackish; fine-grained; break splintery and conchoidal, sometimes uneven. Beds 2 to 12 inches thick, seldom more, well separated from one another. Non-fossiliferous. Here occur the limestones with horizontally embedded, flattish, rounded bodies which give worm-like outlines in cross-section. The bodies here consist mostly of dense black, the matrix of crystalline limestone. These "Wurmkalke" are everywhere characteristic of an upper horizon. Another typical rock is greenish splintery limestone. Total thickness. . . 2000 ft.

L. Globulitic limestones clear gray to black. The Globulites are mostly of the size of oat kernels, seldom as large as peas, beds 2 inches to 2 feet thick. Trilobites abundant . . . . . 500 ft.

K. Green strata. . . . . 80 ft.

I. Globulitic limestones like 1, predominating with dense homogeneous limestones interbedded . . . . 1500 ft.

H. 5. Red clay shales . . . . 120 ft.

4. Gray limestone . . . . 80 ft.

3. Red strata . . . . 80 ft.

2. Dense siliceous limestones of flat conchoidal fracture, very evenly bedded; Whitish, greenish, reddish, prevailingly greenish-white . . . . .200 ft.

1. Red clay shales . . . . .100 ft.

G. Gray dense limestone finely crystalline . . 400 ft.

In the Hsi-ping-shan, southern Chi-li, Richthofen observed Globulitic and conglomeratic strata underlain by red shales. The section has been already described in connection with the pre-Sinisian systems. (see p 59).

Shan-si.

In the Ta-tung-fu coal field, northern Shan-si, the Sinisian limestone is unconformably overlain by Jurassic coal measures, with a marked difference of dip. (see section No. 14)

In northeastern Shan-si, the Sinisian rocks exhibit nearly all the peculiarities of their equivalents in Shan-tung, but here only two lithological divisions can be readily distinguished. According to Willis and Blackwelder they are:

(B) Upper. Ki-Chou limestone.
Gray limestohe.

(A) Lower. Man-to series.
Sandstone, red shale and impure limestone.

The rocks are exposed near Ning-shan, along the southern edge of the Wu-tai-shan district, and on the northern flank of the Wu-tai range.

The lower Man-to series sometimes unconformably overlies the Tai-shan complex (see sections 12, 13), and sometimes rests unconformably upon the Wu-tai (see section 172) or the Hu-to rocks with local basal conglomerate. Moreover, the unconformity between the Sinisian and the pre-Sinisian in these districts is shown by striking discordance between the Sinisian and the pre-Sinisian strata, and the truncation of dykes intruded into the pre-Sinisian at the junction between the lowest Man-to stratum and the older eroded pre-Sinisian beds.

The following section given by Blackwelder represents a part of the Sinisian system as exposed at the south of Tung-yu, Shan-si. It may be regarded as a typical developement of the Sinisian system in N.E.Shan-si and S.W. Chi-li. The upper part of the system has been obviously denuded away.

Ki-chou limestone.	Dense Blue limestone, with fossils Se 33, Si 110	20 ft.
	Ocherous, gray, dense, conglomeratic limestone with fossils Si 66, Si 24.	75 ft.
	Massive, ocherous gray limestone.	110 ft.
	Brown and gray shales and thin bedded limestone with fossils Se 17, Sf 9, Sg 12, Si 16 Si 122, Si 128.	65 ft.
	Massive gray oolitic limestone with fossils Sg 12, Se 11, Se 26, Se 20, Si 1, Si 15, Si 16, Si 135, Si 150.	45 ft.
	Gray shales	15 ft.
	Gray crystalline limestone	9 ft.
	Gray calcareous shale	8 ft.
	Oolitic limestone	5 ft.
	Gray and buff shales with limestone nodules with fossils Si 74, Si 128, Si 64, Si 49, Si 159.	30 ft.
	Hard brown-gray oolitic limestone	12 ft.
	Slabby buff limestone dense and hard with fossils Sf1, Sf 12, Si 77, Si 65, Si 62, Si 48.	35 ft.

Man-to shales.	Red shale and argillaceous limestone with thin yellow limestone	40 ft.
	Red shale and thin limestone	30 ft.
	Argillaceous yellow limestone	4 ft.
	Red calcareous shale	12 ft.
	Red sandstone and conglomerate	3 to 15 ft.
(unconformity.)		
Pre-Sinisian	Purple argillites; siliceous limestones and dykes of green-stones.	

In the valley of O-shui, north of the Wu-tai-shan and south of Tai-chou, magnificent exposure of the Ki-chou limestone resting on the Man-to shale, has been described by Richthofen.[90] The limestone forms precipitous cliffs, and attain a thickness of about 2700 feet.

The upper part of the Ki-chou limestone generally contains few fossils except scattered specimens of orthoceras, coiled gastropods and other Ordovician forms.

In a narrow gorge, on the west side of the Sing-ho, below the city of Wu-tai-hsien, fossils were collected at about 10 feet above the base of the Ki-chou limestone which is underlain by red-brown Man-to shale. The fauna consists of the following forms:[174]
Sc 1, Se 10, Se 34, Si 61, Si 65, Si 73, Si 76, Si 38.

Central China.

The gorge district of the middle Yang-tze.

The dissected broad anticline of the middle Yang-tze district affords splendid opportunity for studying the stratigraphy of the district. Various observations have been made at different times by different geologists. Although the records of the observations vary in detail, they generally agree in showing the main divisions of the sequence of the rocks. Broadly speaking we are able to distinguish two lithological divisions as far as the Sinisian formation is concerned:

(b)	Upper.	Ki-sin-ling limestone. Massive gray limestone which grades downwards into slaty limestone and shales.
(a)	Lower.	Nan-tou series. Tillite, sandstone and conglomerate.

At Nan-tou, a place which is situated at the northwestern entrance of the I-chang gorge, Western Hupeh, Blackwelder describes the following section: (compare section 37)

Ki-sin-ling limestone.	(Massive brown-gray dolomitic (limestone.	4000 ft.?
	(Gray cherty limestone. (Light gray oolitic limestone (White arenaceous limestone (Black argillaceous limestone Brown calcareous shale (Black slaty limestone & flint (Brown shale (Thin sheet of conglomerate (with pebbles like those in (the underlying tillite, and (a matrix of greenish argill- (aceous limestone.	. . . . . 250 ft.

(Unconformity) ————————————

Nan-tou series.

(Glacial tillite . . . . 120 ft.
(On this tillite Blackwelder writes
("Hard massive boulder-clay or tillite
(which is niether 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, brown-rhyolite-porphyry,
(mica-schist, massive green slate, earthy
(gray limestones, quartz and chert.
(- - - -The forms of the majority of the
(stones are subangular, i.e., angles are
(present, but are smooth and rounded. The
(flattish surfaces of such slowly weath-
(ering rocks as the massive silieeous
(ferruginous limestone are polished and
(scratched in various directions - - - -
(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 imbedded
(there in early palaeozioc time".
(Commenting on this description, the writer
(agrees with Blackwelder in regarding these
(deposits as true tillite; The shape of the
(scratched pebbles, their firm setting in an
(undisturbed matrix, etc disavow the possi-
(bility of attributing the striation to
(slickensides.
(
(Obscured by soil . . . . 100 ft.

(Coarse, gritty, quartzite white sandstone.)
(Purplish-brown arkose sandstone.)
(Conglomerate.) 150 ft.
(The pebbles in the conglomerate consist)
(almost entirely of small fragments of the)
(underlying Hwang-ling granite.)

(unconformity) ——————————————————

Hwang-ling granite of pre-Sinisian age.

At the lower entrance of the Lu-kan gorge,[75] Pumpelly observed that quartzite immediately underlies limestone which contains lenticular masses of flints. Apparently, there the tillite is absent.

Between the Lu-kan and Mi-tsang gorges, E.C.Abendanon found a purplish-brown limestone containing coiled nautilus and large casts of orthoceratites. After studying the section given by Blackwelder, Abendanon refers this limestone to the Ki-sin-ling limestone. Here the Ki-sin-ling limestone is underlain by schist and overlain by green shale according to Abendanon. (see p 83)

Near Mau-ping-pu, between San-tou-ping and the upper part of the Mi-tsang gorge, Richthofen observed the following sequence:[104]

8. (see p 181)

7. Gray-green sandstone with greenish shaly strata. . . . . 300 ft.

6. Thick-bedded, gray-black and yellow limestone . . . . 1100 ft.

5. Thin-bedded limestone. . . . . .1200 ft.

4. Thick-bedded, blackish dark sandstone striking N by W.

3. Very hard schistose-rock of gray-green colour, partly due to the presence of mica, chlorite and hornblende. The rock is traversed by granitic veins and dip vertical.

2. Dark rock traversed by granite (Syenitic granite of Pumpelly) with white plagioclase, quartz etc.

1. Granite of San-tou-ping.

(Note - - - - - It seems to be highly probable that an unconformity exists between the base of bed No. 4 and the underlying rocks as suggested by the striking contrast of the nature of the rocks. This unconformity may be identical with the unconformity between the base of the Nan-tou series and the underlying Hwang-ling granite as described by Blackwelder.)

Between Kong-lin-tan and Sin-tan, Noda describes the following sequence:[66] ~~(Jap Bull vol. XXV p 37 No. 1. 1915.)~~

5. Upper shale = Sin-tan shale ~~by~~ of Blackwelder. greenish shale, becomes sandy upwards.

4. Pin-shan-Ba limestone . . . . 400 ft.

3. Lower shale . . . . 150 ft. greenish shale with lenticular mass of limestone.

2. Niu-kan limestone . . . . 300 ft.

1. Nan-tou series . . . . 220 ft.

Sandstone and shales with lenticular mass of limestone and slates with a thin basal layer of sandstone.

In the gorge district, Willis and Blackwelder did not observe the upper limit of the Ki-sin-ling limestone; but they infer that the Ki-sin-ling limestone is probably overlain by the Sin-tan shale, a greenish shale (to be described later) this inference is borne out by the observations made by Richthofen and Abendenon as cited above.

The district near the Ki-sin-ling.[176]

The Ki-sin-ling limestone is well exposed along the divide between N.W.Hupeh and N.E.Su-chuan. In this district the upper part of the same formation consists of an alternation of soft green calcareous shales with thin strata and nodules of limestones of gray and white colours about 200 feet thick. These are separated from the overlying Sin-tan shale by a hard light coloured limestone and a thin stratum of dense black chert. In the shales and the thin gray limestones, trilobites, brachiopods occur in abundance. In the more massive limestone directly beneath the shales there are also numerous well-preserved casts of Orthoceras.

At a rocky narrow on the Ta-ning-ho, about 1.5 miles up the river from Su-kia-pa, the thin gray limestone which forms the upper zone of the Ki-sin-ling limestone, contains the following forms:

Sh 3, Se 49, Se 52, Se 53, Se 54, Sh 4, Si 196.

Si 193, Si 191, Si 197, Si 201, Si 198.

Near the mouth of the ravine immediately northeast of Su-kia-pa, in the similar gray limestone associated with green shales the following forms occur:

Se 49, Se 55, Se 56, Se 53, Se 57, Se 52, Se 54, Se 58.

Si 204, Si 199, Si 191 (of Si 190), Si 194, Si 192, Si 191,

Si 197, Si 200, Si 195, Si 202.

Blackwelder states that by a river bed about a mile above Chou-ping-hsien he found pebbles of gray-green oolitic limestone, pisolitic and conglomeratic limestone, and slaty black limestone, all resembling in a measure, certain phases of the lower Sinisian rocks in Shan-tung. In the limestone pebbles the following fossils were discovered:

Se 18, Se 19, Se 11, Sg 11, Si 5, Sj to Sj 6.

S.W.China.

Eastern Yun-nan.

The presence of Cambrian formation in Eastern Yun-nan was first discovered by Lantenois who collected a few species of brachiopods (Obolella, Lingulella, Discina) and a trilobite which is described by Mansuy as Olenellus (Mesonacis) verneani n. sp.[39]

The recent research of Dr. Deprat in the same region has thrown much light upon the stratigraphy of the cambro-Ordovician formations. The said author distinguishes the Ordovician from the Cambrian on account of the discovery of certain typical Ordovician forms and divides the Cambrian into two stages:

(b) upper stage

Argillaceo-arenaceous group) ptychoparian formation.) Redlichian formation.

(a) Lower stage,

Compact grits with intercalated limestone containing Redlichia.

A. Cambrian.

The Cambrian formation is extensively exposed in Eastern Yun-Nan between the latitude of Yun-nan-fu and the river Kin-sha-kiang, and attains a thickness of at least 2000 m. . Although the formation covers a wide area in the region in question, it is rare to find a complete sequence of the beds as a consequence of complex tectonic movement: The strata are much broken up and even overthrusted, and the rocks are often rendered schistose. In spite of this difficulty, Deprat is able to give us the following stratigraphical records which we may consider as sufficient to warrant the establishment of the divisions indicated above.

In the district of Ho-tein,[7] N.W. of Po-shi, the Cambrian is only represented by its lower part which consists of (see section 55)

5. Thin-bedded yellow sandstone . . . . . . 30 m.
   with Si 9,

4. Micaceous and very sandy yellow grits . . . 70 m.
   with Si 181, Si 180.

3. Green sandy micaceous rock . . . . 60 m.
   with Si 181.

2. Green grits and quartzite with inter-
   calcation of fissile yellow sandy shale . 120 m.
   with Sd 1.

1. Wine-red marly limestone, destitute of
   fossil . . . . 110 m.

At Si-yang-tang (or Tsin-shouei-keuou) to the north of Eul-long-si-shou, an apparent break exists between the Cambrian and the Ordovician. Certain upper Cambrian beds which are well-developed in the neighbourhood of the Siu-kai-tsen and elsewhere in eastern Yunnan are absent in this district. It is uncertain as to whether the said break is brought about by the overthrusting of the Ordovician strata upon the upper Cambrian beds. On this question Deprat writes:

"Cette absence est probablement le resultat d'une lacune locale d'ordre tectonique que le parallelisme de l'ensemble des assises ne permet malheureusement guère d'affirmer. On ne peut accepter l'hypothèse d'une transgression directe de l'Ordovicien sur les couches à Redlichia chinensis et Redlichia carinata puisqu'à une faible distance, à 20 K.M. au S., la horizon supérieur à ptychoparia yunnanensis offre un puissant developpement. L'Ordovicien schisto-marneux est du reste extremement brisé."

The sequence of the Cambrian strata at Si-yang-tang as made out by Deprat is as follows; (see section No.54)

Ordovician - - - - - - - - - - - - (see p 124)

(Break?) ————

Cambrian.	Upper stage.	7. Fine, Marly yellow grits with Si 180, Si 181. 6. Yellow and rose-red ~~tender~~ soft marl with Si 7, Sd 1.	200 m.
		5. Green Sandy shale with Se 59.	10 m.
	Lower stage.	4. Gray limestone	20 m.
		3. Quartzite gray grits	130 m.
		2. Gray limestone.	20 m.
		1. Arkose and quartzitic green grits	100 m.

Near the village of Yi-long, east of Shi-kai-tsen, strata belonging to the upper stage of the Cambrian are exposed. They are as follows: (see section No 53)

Ordovician 9 . . . .

Cambrian.	8. Fine yellow shale sometimes ~~rosy~~ reddish	30 m.
	7. Marl and sandstone prevailingly gray	10 m.
	6. Green or gray shaly sandstone	70 m.
	5. Gritty sandstone with Se 6, Se 7, Si 185, Sg 5.	40 m.
	4. Rosy Marl with Se 43, Se 42, Si 205.	100 m.
	3. Green shaly sandstone with Se 59.	20 m.
	2. Yellow or ~~rosy~~ red marly shale with intercalated sandy layers	80 m.
	1. Green Arkose sandstone	
	2 & 1 contain Se 60, Sj 9, Sj 7, Si 7.	

In the vicinity of La-ni-tang which lies in the valley of the Pa-tzen.ho, (between Lao-chou-to and Tien-houi) the following Cambrian strata are exposed:

9. A series of green and ~~rosy~~ red sandstone with intercalated greenish hard marl . . . . 110 m.

8. Green scaly and noduler marl with greenish sandy, bands . . . . 200 m.
with Se 7, Se 21, Si 184, Si 206, Se 60 Sj 10.

7. Gritty sandstone with three sets of joints which divide the rock into prallelopipeds . . . . 50 m.
with Se 61, Si 205, Se 6, Si 9.

6. Fissile, ~~rosy~~ red marl with intercalated bands of gritty sandstone . . . . 160 m.
with Se 46, Se 60, Si 181, Si 180, Si 7, Sj 9.

5. Green marl and fine.grained, green sandy shale . . . . .30 m.
with Se 59, Si 207.

4. Dull, Highly Calcareous marl and black shale 70 m.

3. Crystalline gray limestone. . . . . 35 m.

2. Fissile shale of ~~rosy~~ red and yellow colour. . . 45 m.

1. Thick-bedded gray and compact sandstone. . . 200 m. ?

B. Ordovician.

According to Deprat, the Ordovician formation[9] occurs in eastern Yun-nan in narrow bands bounded by mighty dislocations. As a rule, the succession of strata is imcomplete along a single section, and the component beds are often brecciated or otherwise broken up.

~~At~~ To the north of the hill near Si-yang-tang, (see p 121) one of the dislocated bands carrying Ordovician rocks runs in a N.N.E. direction towards Yi-Ko-ssen. A transverse section across this band shows the succession of the Ordovician strata and the underlying Cambrian formation; The latter has been already described in p 121. The Ordovician which overlies the Cambrian consists of the following beds: (see section No. 54)

13. Gray limestone, much broken up, resembling the Cambrian crystalline dolomitic limestone, destitute of fossil . . . . 10 m.

12. Highly decomposed very fine yellowish sandstone and marl . . . . 15 m.

11. Calcareous shale (Calcachist) and micaceous black shale . . . . 3 m. with Si 203.

10. Decomposed fine, yellow marly sandstone . . . . 10 m.

9. Greenish fissile marl . . . . 30 m.

8. Extremely fissile and tender marly shale with alternating beds of small rolled flints and seams of scaly clay . . 70 m. with Se 47, Se 48, Se 62, Se 49, Se 50, Se 1, Sl 2, Sk 1, Sk 2, Sk 3.

(Break)? ————————————————————

Cambrian . . . . (see p 121)

Ordovician rocks are exposed in the N.E. of Siun-tien.tcheou. Between this prefecture and the lake of Tche-hou-kiang, at the rising behind the village Sias-tou-kao, Deprat observed the following:

5. Massive coarse sandstone with Bothriolepsis. . 100 m.

4. Black, Shaly sandstone bands with Bothriolepsis . . . . 2 m.

3. Coarse, Arkose sandstone . . . . 10 m.

2. Yellow pulverent marl with intercalated bands of gritty sandstone . . . . 80 m.

1. Soft shaly marl with Malacostraces . . . . . 60 m.

S.E.China.

The lower Yang-tze valley.

In this region Richthofen has distinguished three groups of formations of distinctly different lithological type. He regards them as belonging to the Sinisian system; but his inference is not supported by palaeontological evidence, for he did not succeed in finding a single species from the formations in question. The formations are placed by Richthofen in the following order:

C. Ma-tsu limestone.

B. Lu-shan Slate.

A. Ta-hua sandstone.

The following records of observations are extracted from the voluminous work "China" vol. III. They appear to be the basis, on which Richthofen has drawn his inference in determining the stratigraphical position of the three formations.

In the slope of the Ma-tsu-shan which stands on the northern side of the Po-yang lake, Kiang-si, Richthofen observed a series of fine-grained, half.metamorphosed and slightly quartz-veined slates of green-gray, greenish and reddish colour associated with friable brown sandstone. He calls these rocks collectively "Lu-shan slate". The Lu-shan slate is overlain by siliceous dark gray limestone with intercalated shaly and sandy slates which is followed upwards by a white-veined limestone containing masses of hornstone. (Hornstein-Knauern) These limestones are called Ma-tsu limestone. Richthofen states that he was able to recognize, during the later part of his journey, the immense developement of these rocks in southern China, and considers them as Cambrian formation.[105]

Along the northwestern slope of the Ta-hua-shan, southern An-hwei Richthofen made out the following sequence:[106] (see section No.42)

4. Heavily bedded limestone of gray and sometimes red colour with thin hard parting layers. The cross-section of the rock shows banded structure like the limestone of the Ma-tsu-shan; but here the rock is highly crystalline. The individual beds contain breccia-like layers . . . . .about 400 ft.

3. A series of regularly bedded slates and slaty phyllites comparable with the slates of the Ma-tsu-shan . . . . . 1200 ft.

2. Extremely even-bedded shaly, siliceous and calcareous rock, finely grained, breaks into extraordinarily thin laminae . . . . .about 300 ft.

1. Chiefly quartzitic sandstone cemented by sandy and shaly material. The rock is prevailingly red, but frequently green and violet, and rarely brown and yellow. Pebbles brought down by streams from the highest peaks of the Ta-hua-shan were examined by Richthofen who found nothing but the quartzitic sandstone, and hence it is inferred that a large part of the Ta-hua range is probably composed of the same formation. Richthofen calls it Ta-hua sandstone . . . . at least 2500 ft

In southern An-hwei and eastern Kiang-si, between the coal basin of Lo-ping and the young red sandstone basin of Ki-Monn-hsien, there is an extensive exposure of slaty shale which Richthofen calls the Kauling formation.[107] The shale is intercalated by greywacke-like sandstone, and exhibits a prevailing greenish-gray colour, but red, yellow or even white layers are present. The rock is usually highly folded and strikes E.N.E. It is from this formation that the famous porcelain-rock of Kiang-si is obtained.

(Note - - - the lithology of the Kauling shale is comparable with the Lu-shan slate.)

Near Wu-kung-shan[108] about 7 K M E.N.E. of the city of Nan-king Richthofen observed a series of limestone overlain by red sandstone. (of ? upper carboniferous age) The limestone is of blackish colour, fine-grained, finely bedded and crystalline; with veins of calcite. In some parts it is well cemented and in other parts it is quite loose. Parallel, thin, siliceous layers of yellowish-gray colour occur in the limestone; the former easily breaks into leaves. Even in the intercalated marly partings, Richthofen was unable to detect any traces of fossils. The same author says that this very limestone was met by him in the Ma-tsu-shan, near the Po-yang-hu, and it is distributed over an extensive area in the province of Kiang-si. Further he definitely states that it belongs to the upper part of the Sinisian formation. For what reason Richthofen does so, the writer is unable to find out.

Immediately to the east of the city of Nan-king , a hill rises above the loess plain on its southeastern side and the Yang-tze-kiang on its ~~southeastern~~ northwestern side. (Strawshoe channel) This hill is entirely composed of siliceous limestone of lever-brown, yellowish, whitish, and reddish colour which dissolves into a peculiar siliceous spongy breccia. A pure gray-brown limestone with red veins occurs in the upper part of the limestone series, being exposed on the southeastern slope of the hill. In Richthofen's field note he compares this limestone with that of the Ma-tsu-shan and the Mei-hua-shan; and on his geological map he colours it as "Sinicsh"; while as in conclusion of his geological study between Nan-king and Cheng-kiang, Richthofen refers this dolomitic siliceous limestone to "from Silurian to Devonian"[109]

On the N.W. slope of the Lun-shan, west of Cheng-kiang, a globulitic limestone crops out. It is a blackish-brown semi-crystalline limestone with round grains of the similar material as the "matrix". Traces of trilobites and orthoceratites were discovered in it. Richthofen remarks that the lithology of this rock strongly reminds him of the "Sinisch" limestone which is so extensively developed in Liau-tung and Shan-tung, N.E. China. Overlying this formation is a calcareous shaly slate with graptolites which were at first mistaken by Richthofen as plant impressions.[110] (The writer is particularly interested in seeking for the record of the discovery of this fossil in Chinese geology, but unfortunately he only finds a brief indication of its occurrence in this single district.) The graptolitic slates are followed upwards by spongy and cellular quartz-rock and quartzite which is overlain by micaceous slates. The whole sequence strikes N.E. and dips about 45 S.E. The upper part of this sequence is hidden from sight by a lake. (see p 156 and section No 45)

III Correlation.

In Western Shan-tung, Blackwelder divides the Sinisian system into three groups —— The lower Man-to formation, the middle Kiu-lung group and the upper Tsi-nan limestone. Richthofen and Lorenz only divide the system into two groups The "Untersinisch" and the "Obersinisch". Judging from the general description of the lithological nature of these two groups, (see pp 108, 109) it appears to be highly probable that the terms "Untersinisch" of Richthofen and Lorenz, and the "Man-to formation" of Blackwelder in the same province are practically synonymous. Accordingly, the "Obersinisch" of Lorenz and Richthofen would comprise the Kiu-lung group and probably a part of the Tsi-nan limestone of Blackwelder. Failing to find fossils in the upper part of the Sinisian limestone in Shan-tung, and seeing that the same limestone is immediately overlain by coal bearing series, Richthofen has erroneously regarded the upper Sinisian limestone as "Kohlenkalk" which evidently suggests carboniferous age. Lorenz, on the other hand describes the occurrence of "lower Silurian limestone" in Shan-tung and observed erosion unconformity between the so-called Silurian limestone and the overlying coal bearing series. (see section No. 25) By "lower Silurian" obviously Lorenz means Ordovician as proved by the presence of Asaphus Boehmi. It is not clear to the writer whether Lorenz includes the so-called "lower Silurian" in the "Obersinisch" or regards it as a separate system. To avoid confusion, the writer thinks it desirable to regard the subdivision of the Sinisian system in Shan-tung given by Blackwelder as the standard classification.

<u>In Northwestern Chi-li</u>, the succession of the Sinisian strata as exposed in the Nan-kou ~~section~~ pass, (see p 111) shows remarkable parallelism with that in Shan-tung: The series (h) exhibits every lithological peculiarity of the Man-to formation; above (h) there follows a series of globulitic limestones and other strata, (i,k,l,) which corresponds to the oolitic limestones and green shales of the Kiu-lung group in Shan-tung. The limestone (m) resembles the Chau-mi-tien and Tsi-nan limestone, for the development of the peculiar conglomerate, and the general absence of fossils in the upper part of the formations are strikingly characteristic in both cases.

The imcomplete sequence observed by Richthofen in the Hsi-ping-shan, southern Chi-li; (see p 69) shows that the development of the Sinisian formations is essentially the same in that region as in northern Chi-li and Shan-tung.

<u>In Northern Shan-si,</u> the Man-to formation consists of the same material as it does in Shan-tung and Chi-li; The lower Ki-chou limestone which overlies the Man-to formation, contains oolitic and conglomeratic strata, showing strong lithological resemblance to the Chang-hia limestone of Shan-tung. Moreover they have yielded common trilobites and a brachiopod. (see p). Thus it is beyond doubt that the lower part of the Ki-chou limestone is equivalent to the Chang-hia limestone. The zone of the conglomeratic limestone may be conveniently regarded as the divide between the lower and the upper Ki-chou limestone. Above this zone the Ki-chou limestone becomes massive, and contains very few fossils. What have been found near the top of the formation are orthoceras, coiled gastropods and other Ordovician forms. Similar facts are recorded in the Tsi-nan limestone. Hence the upper Ki-chou limestone is considered to be

equivalent, at least in part, to the Tsi-nan limestone.

In the gorge district of the middle Yang-tze and the neighbouring districts the Ki-sin-ling limestone appears to be divisible into two divisions The upper massive dolomitic limestone, and the lower shaly limestone. (see p 115) From the upper part of the upper Ki-sin-ling limestone Orthoceras and other Ordovician forms have been collected. On account of this palaeontological discovery and the massive nature of the rock, we may correlate the upper Ki-sin-ling limestone with the Tsi-nan limestone and the upper Ki-chou limestone. The lower Ki-sin-ling limestone contains a light gray oolitic limestone which resembles certain members of the middle Sinisian in N.E. China. Therefore it probably represents the middle Sinisian in central China. In the absence of palaeontological evidence it must be admitted that this correlation cannot be strongly advocated.

Regarding the lower Ki-sin-ling limestone as middle Sinisian, and assuming that the lower Sinisian time was not represented, in central China, by denudation but by deposition, a series of lower Sinisian rocks underlying the Ki-sin-ling limestone would be demanded. This assumption is rendered possible by the indication of the prolonged peneplanation at the end of the pre-Sinisian period as inferred by Willis. and the quiet and general subsidence of the highly eroded continent without notable relief at the beginning of the Cambrian time throughout China.

The Nan-tou series which underlies the Ki-sin-ling limestone, consists of well-bedded, almost undisturbed red sandstone and glacial deposits. It is separated from the Ki-sin-ling limestone by an unconformity according to Blackwelder; but the same author remarks that the unconformity probably does not represent any appreciable length of time. Indeed it may be a mere local non-sequence. Owing to the presence of this break it appears to be not improbable that the Nan-tou series belongs to the upper pre-Sinisian group; but the undisturbed condition of the strata and the insignificant magnitude of the break (if Blackwelder's suggestion is based on good reason) make it more probable that the said series was deposited in the early Sinisian time; hence we may tentatively regard the Nan-tou series as being equivalent to the Man-to formation in northern China. This inference is strengthened by the interpretation of the physiographical conditions in the early Sinisian time in China: The climate was presumably arctic over a large area of the country. In central China where there was sufficient precipitation glacial conditions prevailed; while in northern China the aridity of the atmosphere prevented the existence of large mass of ice, and induced the extensive formation of laterite from which the red soft marly shales of the Man-to formation are likely to have been derived. The general absence of organic remains in the lower part of the Man-to formation (about 100 ft) is also a fact that tends to show the severely cold climate which rendered the shallow lower Man-to sea thoroughly unsuitable for organisms to live.

<u>In Eastern Yun-nan,</u> (see p119 seq.) the lower stage of the Cambrian consists of gritty material with occasional beds of limestone. In this lower stage the species Redlichia chinensis is found. The same species also occurs in the Man-to formation in Shan-tung. The upper stage of the Cambrian consists of shales, marls, sandstones etc. From the upper part of this stage the species Obolus chinensis, Obolus

damesi, and the genus ptychoparia have been found. These also occur in the Kiu-lung group of Shan-tung. The presence of these forms leads Deprat to compare the Obolus chinensis zone in eastern Yun-nan with the lower part of the Chau-mi-tien limestone in western Shan-tung. The same author points out the lithological difference of the rocks in which the common forms occur in the two regions. The facial difference of a zone in lithology in places which are separated by a great distance, is of course completely within our expectation.

The Ordovician of eastern Yun-nan with the characteristic trilobite Dionide formosa Barrande which occurs at the zone d3, stage D, of the Ordovician formation in Bohemia, is compared by Deprat with the Tsi-nan limestone in Shan-tung. In the latter formation Ordovician fossils also occur as already stated.

The calcareous formation near Tchao-tien (Tshau-tien,) western Su-chuan, (see p 150) which has yielded Asaphus sp, Calymene sp, and Trinucleus richthofeni Kayser; is also compared by Deprat with the Dionide zone of eastern Yun-nan. This correlation is discussed later.

<u>In the lower Yang-tze valley,</u> (see p 125 seq) Richthofen distinguishes three Sinisian formations: — The lower Ta-hua sandstone is regarded by the same author as probably belonging to the lower Cambrian;[111] the upper Ma-tsu limestone and the middle Lu-shan slate are sometimes referred to the Cambrian and sometimes to the Silurian by Richthofen.[112] The writer is not sure as to whether Richthofen did ever arrive at a definite conclusion in classifying and correlating these formations. A fourth formation, the Kauling slate, mentioned by Richthofen also evades classification. As appears in the earlier works of Richthofen, this formation is correlated with

the Lu-shan slate on account of its prevailing greenish colour; but similar remarks are not found in the notes contained in the third volume of "China" Tiessen points out that there is a difference between the nature of the Kauling slate and that of the slate exposed at the lower course of the Hsin-ngan-kiang, Che-kiang. The latter should be regarded as Lu-shan slate according to Tiessen whose inference is drawn from the observation made by Richthofen at the Fonn-shui-ho.[113] Therefore Tiessen thinks that the age of the Kauling slate cannot be the same as the Lu-shan slate and the former may be equivalent to the Wu-tai formation in northern China. This statement opens the question that the Lu-shan slate may belong to the pre-Sinisian systems. Without further data, and above all palaeontological data, the writer is unable to criticise these arguments.

The Globulitic limestone of Lun-shan (see p 128) underlying the graptolitic shale, is postively a Sinisian representative in the neighbourhood of Cheng-kiang.

In glancing over the list No. 1. (showing the Cambro-Ordovician fossils found in China) the writer notes that true Olenellus and other forms which characterize the British, Scandinavian, and eastern North American, Lower Cambrian fauna (The affinity between the Cambrian faunas in these regions has been fully discussed by B. N. Peach[204]) are absent. The species Redlichia chinensis and Redlichia nobilis were originally referred to by Walcott as descendent from Olenellus, but the same author now advances the opinion that the genus olenellus appears to have left no descendents. A species bearing the name Olenellus? forresti as described by A.H.Foord occurs in western Australia in the Kimberley district.[302] The same fossil is regarded by

Walcott as Redlichia. In Spiti, Northern India, Redlichia noetlingi occurs.[304] From these facts and others Walcott concludes that the transgressing Lower Cambrian sea that contained the Redlichia fauna was confined to eastern and southeastern (presumably Walcott means southwestern) China and northern India; and that there is no record pointing to a connection between the "Punjab-Man-to Sea" and the Lower Cambrian seas of Northern Siberia, or Western North America.

The Middle Cambrian fauna of China, as has been pointed out by Walcott, Lorenz and others, shows close affinity to that of North America and northwestern Europe. The absence of the genus paradoxides together with the presence of Dorypyge in China and western North America emphatically argues for the inference that these two regions probably belonged to one and the same life-province in the Middle Cambrian time. It is important to note that the majority of the allies of Dorypyge found in China are also the allies of paradoxides in eastern North America; further, Gronwall has shown that Dorypyge is associated with paradoxides, Amomacare, etc., in northern Europe. Thus we are led to conclude that the Dorypygian zone in China is practically equivalent to the Paradoxidian zone in the western world.

Various species of ptychaspis are present both in the Upper Cambrian of China and the Upper Cambrian of Northern America. It is largely based on the presence of this genus that Walcott assigns Upper Cambrian age to the Chau-mi-tien limestone. The genus Liostracus is, according to Lorenz, a Middle Cambrian form in Scandinavia, but it is found in the Upper Cambrian in Shan-tung.[62]

The fauna found at the top of the Ki-sin-ling limestone shows close affinity to the Trenton fauna of North America and the vaginoceras limestone of the Baltic province of Russia according to Weller. The presence of the genera Asaphus and Dionide proves conclusively that the Chinese Ordovician sea was in communication with that of Europe.

L I S T No I.

FOSSILS FOUND IN CAMBRIAN-ORDOVICIAN ROCKS IN CHINA.

Note I. The reference no. of each species is only used in this thesis for convenience.

2. Nearly all those specific names to which no name of a palaeontologist is attached, are originally given by Dr. C. Walcott. Changes of generic names have been made by Walcott since the publication of the original description of certain genera. Only the latest generic references are mentioned in this list. The previous generic references can be found in "The Smithsonian miscellaneous collections" vol. 64. no. I pp I4-I7.

REFERENCE NO.	NAMES	Stratigraphical position: Lower Cambrian	Middle Cambrian	Upper Cambrian	Ordovician	Originally described in — (See bibliography)	Mentioned in this thesis in p. —
	(a) FORAMINIFERA						
SaI	Globigerina? mantoensis	.	x	.	.	.	
	(b) PORIFERA						
SbI	Protospongia chloris	.	x	.	.	.	
Sb2	Protospongia sp. undt.	.	x	.	.	.	
	(c) ANTHOZOA						
ScI	Coscinocyathus elvira	.	x	.	.	.	
	(d) ANNELIDA						
SdI	Planolites sp. undt.	.	x	.	.	.	
	(e) BRACHIOPODA						
SeI	Micromitra sculptilis	.	x	.	.	.	
Se2	Micromitra (paterina) labradorica orientalis .	.	x	.	.	.	

Se3	Micromitra (Paterina) lucina		x				
Se4	Micromitra (Iphidella) pannula maladensis .		x				
Se5	Micromitra (Iphidella) pannula ophirensis .		x				
Se6	Obolus chinensis		x				
Se7	Obolus damesi		x				
Se8	Obolus matinalis?			x			
Se9	Obolus minimus		x				
SeI0	Obolus obscurus		x				
SeII	Obolus shansiensis		x				
SeI2	Obolus (Westonia) blackwelderi		x				
SeI3	Obolus (Westonia) sp. undt.			x			
SeI4	Lingulella manchuriensis		x				
SeI5	Lingulella marcia		x				
SeI6	Lingulella (Lingulepis) eros		x				
SeI7	Lingulella (Lingulepis?) sp. undt.		x				
SeI8	Dicellomus parvus		x				
SeI9	Obolella asiatica	x					
Se20	Yorkia? orientalis		x				
Se2I	Acrothele mathewi eryx. . . . . Acrothele bohemica Barrande LORENZ Acrothele granulata LINNARSSON		x				
Se22	Acrothele? minuta		x				
Se23	Acrothele rara		x				
Se24	Acrotreta lisani		x				
Se25	Acrotreta pacifica		x				
Se26	Acrotreta shantungensis		x				
Se27	Acrotreta venia		x				

Se28	Discinopsis sulcatus			x			
Se29	Billingsella pumpellyi			x			
Se30	Billingsella richthofeni	x					
Se3I	Eoorthis agreste		x				
Se32	Eoorthis dori			x			
Se33	Eoorthis kayseri			x			
Se34	Eoorthis kichouensis		x				
Se35	Eoorthis linnarssoni . . . . Orthis linnarssoni KAYSER			x			
Se36	Eoorthis pagoda			x			
Se37	Eoorthis sp. indt (a)		x				
Se38	Eoorthis sp. indt (b)		x				
Se39	Huenella orientalis			x			
Se40	Syntrophia orthia			x			
Se4I	Obolella gracilis n. sp. LORENZ . .. . cf. Obolus obscurus WALCOTT						
Se42	Obolus? detritus MANSUY						
Se43	Obolus cf. chinensis WALCOTT						
Se44	Lingula yunnanensis MANSUY						
Se45	Discina MANSUY	x					
Se46	Obolella MANSUY	x					
Se47	Lingula cf. striata SOW				x		
Se48	Lingula deprati MANSUY				x		
Se49	Strophomena sp. undt.				x		
Se50	Spirifer bourgeoisi MANSUY				x		
Se5I	Orthis? or Dalmanella?				x		
Se52	Plectorthis willisi WELLER				x		

Se53	Dalmanella testudinaria DALMAN				x		
Se54	Clitambonites chinensis WELLER				x		
Se55	Triplecia poloi MARTELLI				x		
Se56	Orthis calligramma DALMAN				x		
Se57	Dalmanella subaequata CONRAD				x		
Se58	Hemipromites tenuistriata WELLER				x		
Se59	Acrothele orbicularies MANSUY	?	?				
Se60	Lingulella sp.						
Se6I	Obolus detritus MANSUY						
Se62	Discina (orbiculoidea) chinensis MANSUY . . .				x		
	(f) GASTROPODA						
SfI	Scenella clotho		x				
Sf2	Scenella? dilatatus		x				
Sf3	Scenella sp. undt.			x			
Sf4	Matherella circe			x			
Sf5	Straparollina sp. undt.		x				
Sf6	Pelagiella chronus		x				
Sf7	Pelagiella clytia			x			
Sf8	Pelagiella pagoda			x			
Sf9	Pelagiella willisi		x				
	Raphistoma broggeri LORENZ						
SfI0	Helcionella? clurius		x				
SfII	Helcionella rugosa chinensis	x					
SfI2	Helcionella rugosa orientalis						
SfI3	Helcionella?? simplex		x				
SfI4	Raphistoma broggeri GRONWALL		?				

SfI5	Maclurea longani SALTER				x		
SfI6	Lophospira sp. undt.				x		
SfI7	Maclurea or Helicotoma				x		
	(g) PTEROPODA						
SgI	Hyolithes cybele		x				
Sg2	Hyolithes daphnis			x			
Sg3	Hyolithes delia	x					
Sg4	Hyolithes sp. undt.	x					
Sg5	Hyolithes sp. undt.				?		
Sg6	Orthotheca cyrene		x	x			
Sg7	Orthotheca cyrene dryas		x				
Sg8	Orthotheca daulis		x				
Sg9	Orthotheca delphus		x				
SgI0	Orthotheca cf. delphus		x				
SgII	Orthotheca doris		x				
SgI2	Orthotheca glabra		x				
SgI3	Orthotheca sp, undt.			x			
	(h) CEPHALOPODA						
ShI	Cyrtoceras cambrian			x			
Sh2	Orthoceras sp.				x		
Sh3	Cornulites sp.				x		
Sh4	Vaginoceras sp.				x		
Sh5	Cf. Ormoceras tenuifilum HALL				x		
Sh6	Orthoceratites.				x		

	(i) TRILOBITA						
Si1	Agnostus chinensis DAMES.		x				
	Agnostus fallax laiwuensis LORENZ						
Si2	Agnostus douvillei		x				
	Agnostus koerferi MONKE						
Si3	Agnostus kushanensis		x				
Si4	Agnostus parvifrons latelimbatus		x				
	? Agnostus parvifrous LINNARSSON						
Si5	Microdiscus orientalis		x				
Si6	Shumardia sp. undt.		x				
Si7	Redlichia chinensis	x					
Si8	Redlichia ? finalis		x				
Si9	Redlichia nobilis	x					
Si10	Redlichia sp. undt. (a)		x				
Si11	Redlichia sp. undt. (b)	x					
Si12	Redlichia sp. undt. (c)	x					
Si13	Albertella pacifica		x				
Si14	Dorypyge bispinosa		x				
Si15	Dorypyge richthofeni DAMES		x				
	Olenoides (Dorypyge) richthofeni DAMES						
Si16	Dorypyge (Dorypyge) laevis		x				
Si17	Teinistion alcon		x				
Si18	Teinistion lansi MONKE		x				
Si19	Teinistion typicalis		x				
Si20	Stephanocare ? monkei		x				
Si21	Stephanocare richthofeni MONKE		x				
Si22	Stephanocare ? sinensis		x				
Si23	Blackwelderia alastor		x				

Si24	Blackwelderia clix		x				
Si25	Blackwelderia sinensis . . . . Calymene ? sinensis BERGERON		x				
Si26	Damesella bellagranulata		x				
Si27	Damesella blackwelderi		x				
Si28	Teinistion (?) sp.,						
Si28'	Drepanura (?) sp. LORENZ						
Si29	Teinistion brevicaudata		x				
Si30	Drepanura ketteleri MONKE		x				
Si3I	Drepanura premesnili MONKE		x				
Si32	Ptychoparia aclis	x					
Si33	Ptychoparia granosa	x					
Si34	Ptychoparia impar	x					
Si35	Ptychoparia impar var. ?		x				
Si36	Ptychoparia kochibei.		x				
Si37	Ptychoparia ligea	x					
Si38	Ptychoparia lilia		x				
Si39	Ptychoparia ? tolus	x					
Si40	Ptychoparia typus . . . . Conocephalites typus DAMES		x				
Si4I	Ptychoparia (Emmrichella) bromus		x				
Si42	Ptychoparia (Emmrichella) mantoensis	x					
Si43	Ptychoparia (Emmrichella) constricta	x					
Si44	Ptychoparia (Emmrichella) eriopia		x				
Si45	Ptychoparia (Emmrichella) theano		x				
Si46	Conokephalina belus			x			
Si47	Conokephalina dryope			x			
Si48	Conokephalina maia		x				

Si49	Conokephalina vesta	x				
Si50	Crepicephalus convexus	x				
Si5I	Crepicephalus damina	x				
Si52	Crepicephalus magnus	x				
Si53	Lonchocephalus tellus	x				
Si54	Liostracina krausei MONKE	x				
Si55	Proampyx burea		x			
Si56	Pterocephalus asiaticus	x				
Si57	Pterocephalus busiris		x			
Si58	Shantungia spinifera	x				
Si59	Inouyia abaris	x				
Si60	Inouyia ? acalle	x				
Si6I	Inouyia armata	x				
Si62	Inouyia capax	x				
Si63	Inouyia divi	x				
Si64	Inouyia ? inflata	x				
Si65	Inouyia melie	x				
Si66	Inouyia regularis	x				
Si67	Inouyia thisbe	x				
Si68	Inouyia titiana	x				
Si69	Agraulos abrota	x				
Si70	Agraulos dirce	x				
Si7I	Agraulos dolon	x				
Si72	Agraulos dryas	x				
Si73	Agraulos nitida	x				
Si74	Agraulos obscura	x				

Si75	Agraulos sorge		x				
Si76	Agraulos uta		x				
Si77	Agraulos vicina		x				
Si78	Pagodia bia			x			
Si79	Pagodia dolan			x			
Si80	Pagodia lotos			x			
Si8I	Pagodia mocedo			x			
Si82	Lis ania agonius		x				
Si83	Lis ania ajax		x				
Si84	Lis ania alala		x				
Si85	Lis ania ? belenus		x				
Si86	Lisania bura		x				
Si87	Lisania cf. bura		x				
Si88	Lisania sp. undt.		x	x			
Si89	Solenopleura agno		x				
Si90	Solenopleura beroe		x	x			
Si9I	Solenopleura chalcon		x				
Si92	Solenopleura intermedia		x				
Si93	Solenopleura pauperata		x				
Si94	Chuangia batia			x			
Si95	Chuangia fragmenta			x			
Si96	Chuangia nais			x			
Si97	Chuangia nitida . . . . Schantungia buchruckeri LORENZ			x			
Si98	Menocephalus abderus		x				
Si99	Menocephalus acanthus		x				
SiI00	Menocephalus acerius		x				

SiI0I	Menocephalus acidalia	x				
SiI02	Menocephalus acis	x				
SiI03	Menocephalus admeta	x				
SiI04	Menocephalus agave	x				
SiI05	Menocephalus ? depressus		x			
SiI06	Levisia adrastia	x				
SiI07	Levisia agenor	x				
SiI08	Ptychaspis acamus		x			
SiI09	Ptychaspis baubo		x			
SiII0	Ptychaspis bella		x			
SiIII	Ptychaspis brizo		x			
SiII2	Ptychaspis vacus		x			
SiII3	Ptychaspis cadmus		x			
SiII4	Ptychaspis calchas		x			
SiII5	Ptychaspis callisto		x			
SiII6	Ptychaspis calyce		x			
SiII7	Ptychaspis campe		x			
SiII8	Ptychaspis ceto		x			
SiII9	Anomocare alcinoe	x				
SiI20	Anomocare daulis	x				
SiI2I	Anomocare ephori	x				
SiI22	Anomocare flava	x				
SiI23	Anomocare latelimbatum DAMES . . . . Lioparia latelimbatum (dames) LORENZ	x				
SiI24	Anomocare lisani	x				
SiI25	Anomocare megalurus . . . . Liostracus megalurus DAMES	x				

SiI26	Anomocare minus	x				
SiI27	Anomocare minus var.	x				
SiI28	Anomocare ? nereis	x				
SiI29	Anomocare subquadratum	x				
	Conocephalites subquadratum DAMES					
SiI30	Anomocare Sp. undt.	x	x			
SiI3I	Anomocare subcostatum DAMES	x				
SiI32	Anomocarella albion	x				
SiI33	Anomocarella baucis		x			
SiI34	Anomocarella bergioni		x			
SiI35	Anomocarella bigsbyi	x				
SiI36	Anomocarella biston	x				
SiI36'	Anomocarella butes	x				
SiI37	Anomocarella chinensis	x				
	Anomocare commune LORENZ					
SiI38	Anomocarella comus	x				
SiI39	Anomocarella hermias	x				
SiI40	Anomocarella irma	x				
SiI4I	Anomocarella macar	x				
SiI42	Anomocarella subrugosa	x				
SiI43	Anomocarella speciosa LORENZ	x				
	Anomocare speciosum LORENZ					
SiI44	Anomocarella tatian	x				
SiI45	Anomocarella temenus	x				
	Anomocare ovatum LORENZ					
SiI46	Anomocarella tenes	x				
SiI47	Anomocarella toxeus	x				
SiI48	Anomocarella trogus	x				

SiI49	Anomocarella tutia		x				
SiI50	Anomocarella undata		x				
SiI5I	Coosia ? bianos			x			
SiI52	Coosia carme			x			
SiI53	Coosia ? daunus		x				
SiI54	Coosia decelus		x				
SiI55	Dolichometopus alceste		x				
SiI56	Dolichometopus deois . . . . Amphoton steinmanni LORENZ Bathyuriscus asiaticus LORENZ		x				
SiI57	Dolichometopus dercete		x				
SiI58	Dolichometopus dirce		x				
SiI59	Dolichometopus hyrie		x				
SiI60	Hysterolenus ? sp. undt.			x			
SiI6I	Bathyuriscus manchuriensis		x				
SiI62	Asaphiscus iddingsi		x				
SiI63	Tsinania canens n.g.			x			
SiI64	Tsinania ceres n.g.			x			
SiI65	Tsinania dictys n.g.			x			
SiI66	Conocephalites frequens DAMES		x				
SiI67	Conocephalites quadriceps DAMES		x				
SiI68	Anomocare majus DAMES		x				
SiI69	Anomocare nanum DAMES		x				
SiI70	Anomocare planum DAMES		x				
SiI7I	Anomocare subcostatum DAMES		x				
SiI72	Liostracus talingensis DAMES		x				
SiI73	Arthricocephalus chauveaui BERGERON	?	?	?			

SiI74	Agnostus koerferi MONKE ? Agnostus chinensis DAMES		?	?			
SiI75	Teinistion sodeni MONKE		?	?			
SiI76	Liostracus latus LORENZ			x			
SiI77	Teinistion ? sp. LORENZ Damesella cf. blackwelderi WALCOTT		x				
SiI78	Drepanura ? sp. LORENZ Damesella cf. blackwelderi WALCOTT		x				
SiI79	Pagodia monkei (LORENZ) WALCOTT Lioparia latelimbata (DAMES) LORENZ			x			
SiI80	Redlichia walcotti MANSUY	x					
SiI8I	Redlichia carinata MANSUY	x					
SiI82	Palaeolenus douvillei MANSUY						
SiI83	Palaeolenus lantenoisi MANSUY						
SiI84	Palaeolenus deprati MANSUY		?				
SiI85	Ptyoparia yunnanensis MANSUY		x				
SiI86	Agnostus pii n. sp.						
SiI87	Microdiscus paronai n. sp.						
SiI88	Olenoides paronai n. sp.						
SiI89	Asaphus boehmi n. sp. LORENZ				x		
SiI90	Asaphus expansus				x		
SiI9I	Asaphus sp. (several)				x		
SiI92	Asaphus chinensis WELLER				x		
SiI93	Asaphus laevis WELLER				x		
SiI94	Asaphus asiaticus WELLER				x		
SiI95	Calymene ? sp.				x		
SiI96	Ampyx sp. (cf. Ampyx costatus BOECK)				x		
SiI97	Isotelus sp.				x		

SiI98	Proctus sp.				x		
SiI99	Bathyurus sp.				x		
Si200	Illaenus (?) bronteoides WELLER				x		
Si20I	Megalaspis minor WELLER				x		
Si202	Pterygometopus (?) sp.				x		
Si203	Dionide formosa BARR				x		
Si204	Ampyx chinensis WELLER				x		
Si205	Redlichia sp..	x	?				
Si206	Ptychoparia sp.		?				
Si207	Discina sp.						
	(j) OSTRACODA						
SjI	Aluta bergeroni		x				
Sj2	Aluta enyo		x				
Sj3	Aluta eris		x				
Sj4	Aluta fragilis		x				
Sj5	Aluta sterope		x				
Sj6	Aluta woodi		x				
Sj7	Aluta sp.		x				
Sj8	Bradoria douvillei MANSUY						
Sj9	Nothozoe						
SjIO	Bradoria sp.						
	(k) PHYLLOCARIDA						
SkI	Sinocaris asiatica MANSUY				x		
Sk2	Sinocaris barbagei MANSUY				x		

Sk3	Certiocaris pierloti MANSUY				x			
	(1) LAMELLIBRANCHIA							
Sl1	Leda circumflexa MANSUY				x			
Sl2	Goniophora contrassia MANSUY				x			

SILURIAN — DEVONIAN.

(1) General Remarks.

The researches of Richthofen, Lorenz, Willis and Blackwelder, and others have shown that in northern China, the Sinisian system and the overlying Shansian system are separated by an unconformity of great magnitude. The top of the Sinisian contains fossils which indicate ordovician age as already mentioned; the base of the overlying system, yields marine fossils. The exact age of these fossils, although is still a matter of dispute, they undoubtedly represent the life of a period not earlier than lower carboniferous; [they may prove to be upper carboniferous or even permo-carboniferous forms]. From these palaeontological data it follows that Siluro-Devonian deposits are practically absent in northern China, i.e., in the province of Shan-tung, Chi-li, Shan-si and probably Shen-si. Either during the whole of this period or a part of it, these provinces must have been subjected to erosion. Whatever might be the geological processes that had operated in the said regions throughout the Siluro-Devonian period, the net result of them was to produce a scanty stratigraphical record.

In northwestern China, in the Nan-shan region Obrutchov[19] collected a few fossils which may be regarded as indicating the presence of Devonian formation. He also observed "Silurian" rocks in the same region.

In central China, a group of gneiss and schists is exposed in the southern part of the western Tsing-ling-shan. These gneiss and schists are mapped by Richthofen as " "probable Silurian". On the southern flank of the Ta-pa-shan, (see physiography p 15) near the northern border of the Red Basin of Su-chuan, Richthofen found a marine formation of incontestable Silurian age. Siluro-Devonian deposits of argillaceous composition also occur in between Ki-sin-ling (lat. 31° 50'N. long. 109° 30'E.) and the gorge district of the middle Yang-tze.

In the lower Yang-tze region, the ? Devonian formation is largely represented by coarse gritty material which, in one known case, overlies graptolitic shale of ? Silurian age.

In southwestern China, both Silurian and Devonian rocks have been discovered. The latter is generally a massive marine formation spreading over large areas in the provinces of Yun-nan, Kwei-chou, Kwang-si and probably Hu-nan, and containing abundant organic remains.

The nature of the junction between the Ordovician and Silurian formations in China is ill-understood except in the middle Yang-tze region where the conformable and gradual passage from the Ki-sin-ling limestone (Ordovician) to the Sin-tan series (Siluro-Devonian) has been clearly described by Blackwelder. Judging from the information furnished by Richthofen and Deprat, it appears to be probable that there is no conspicuous break between Ordovician and Silurian in S.E.

and S.W.China. This statement, of course, is qualified by the limited observations made by the two geologists.

The junction between the Silurian and the Devonian in S.E.China is not definitely known, since the determination of the age of the so-called Silurian and Devonian rocks in this region is not conclusive. If we assume that the so-called Silurian and Devonian are also true Silurian and Devonian formations, the striking lithological difference between them seems to suggest that earth movement of notable magnitude probably occurred during the Siluro-Devonian period; for the lower part of the Siluro-Devonian group consists of fine material, while the upper part of it is generally composed of coarse sediments which often merge into massive conglomerate showing the result of vigorous erosion.

Similar lithological change at the junction between the Silurian and Devonian has not been observed in western China nor is there any notable discordance of stratification that has been discovered amongst the Siluro-Devonian strata in the same region. In all probability, the Silurian passes conformably into Devonian in western China. In the middle Yangtze district, the whole of the Siluro-Devonian strata constitutes a conformable sequence according to Blackwelder. But, in S.W.China the Devonian is sometimes found to rest at once on "pre-cambrian" rocks, and sometimes it overlies the Redlichian formation of lower cambrian age.

The junction between the upper Devonian and the lower carboniferous in the north of Su-chuan, western China, appears to be a conformable one as far as Richthofen's observation is concerned. In the middle Yang-tze district, the Siluro-Devonian formation (Sin-tan series) is overlain by the carboniferous limestone (Wu-shan limestone). according to Blackwelder. In many districts in the lower Yang-tze valley there is a pronounced difference of lithology between the coarse Devonian sediment and the overlying calcareous carboniferous formation; but Richthofen does not mention any discordance of stratification and other facts pointing towards an unconformity. In S.W.China, both Leclere and Depart states that there is no break between the Upper Devonian and the lower Carboniferous.

Lorenz speaks of Devonian transgression in Shan-tung on account of the presence of coarse deposits between the eroded Sinisian limestone and the first fossiliferous horizon above it; the latter yields forms which are most likely to belong to the upper carboniferous or even the permo-carboniferous period. In the absence of an unconformity between the fossiliferous horizon and the said coarse sediments which attain a total thickness less than 100 m, the presumption is strong that these coarse sediments are a Carboniferous formation rather than Devonian. Therefore the writer is not inclined to accept Lorenz's hypothesis.

The fossils found in the Silurian rocks in China, are chiefly confined to a locality near Ning-kiang-tshou, north of Su-chuan where Richthofen made out the classical section of Siluro-Devonian strata, (see section No.32). A few Silurian species are also known in eastern Yun-nan and elsewhere.

The more important forms are Favosites forbesi, F.fibrosus, Halisytes catenularius, Heliolites, Orthis Calligramma, O. bouchardii, Strophomena, spirifer, Atrypa, Orthoceras, Modiomorpha, etc.

The rich Devonian fauna found in central and S.W.China chiefly consists of brachiopods and corals. Among the characteristic forms we may count Spirifer curvatus, S.verneuili, Atrypa reticularis, A. aspera, Rhynchonella (pugnax) pugnus, Productella subaculeata, Uncites gryphus, chonetes orientalism Cyathophyllum caespitosum, C. helianthoides, C.roemeri, Favosites sphaericus, Calceola sandalina, Alveolites, Cardiola, etc. The small branching coral Aulopora appears to be a widely distributed typical Devonian form in China.

(II) Field Observations.

(Under this heading fossils are mentioned by reference numbes numbers; their generic and specific names are found in list No. 2)

S.W.China.

Eastern Yun-nan.

In eastern Yun-nan, Deprat has distinguished the Silurian or Gothlandian from the Devonian. Accordingly, they are separately described in the following pages.

A. Silurian.

To the north of the latitude of Yun-nan-fu (about 25° 20'N.) in eastern Yun-nan, Deprat found a series of gray shaly sandstone which crops out between the village of Hoang-li-tsuen, south of Lou-lan, and the little pagoda situated at Mi-chemin by the side of the road running between Hoang-li-tsuen and Hai-men-kiao. The lower part of the series was not examined by Deprat for it breaks up in an abnormal manner against the ptychoparian Cambrian. On the southern side the exposure ends in a compact gritty sandstone which according to Deprat, is identical with those overlying the Ordovician elsewhere in eastern Yun-nan. (see p 124) Southward, the compact gritty sandstone is quickly buried by the transgressive carboniferous limestone visible in front of Hai-men-kiao. The exposure extends towards E.N.E., and the strata strike N.N.E. which is also the strike of the rocks overlying the Ordovician in the basin of the Tchang-hi-ho. Deprat assigns this sandy series to the Silurian, and gives the following sequence:[11]

(5) A series of mottled, shaly sandstone with the intercalation of a scaly marl, the Hoang-li-tsuen marl; and contains S D a 1 - - - - - - - - - - - 70 m.

(4) Unfossiliferous gray sandstone - - - 20 m.

(3) Unfossiliferous gray limestone - - - 10 m.

(2) Yellowish-gray shaly sandstone exposed near the pagoda of Ma-la-ly, and contains the following - - - - -50 m. fossils SD a 2, SD b 1, SD b 2, SD b 3, SD z 1.

(1) Compact gritty sandstone, of which only the upper part is visible, ~~is visible.~~ Near Nan-ti, south of Yun-nan-fu, Deprat discovered a shale which contains Spirifer tonkinensis. On account of the presence of this fossil, Deprat regards this

shale as probably being the passage bed from upper Silurian to lower Devonian.[12]

B. Devonian.

The Devonian formation attains a magnificent development in eastern Yun-nan. The rich fauna that it contains has made it the best known formation in S.W.China for a long time past. The French expedition of the Me-kong was the first to announce the presence of Devonian limestone in the province of Yun-nan. Dr. Joubert[33] made a bold attempt to classify all the limestones in Yun-nan as Devonian, but in this respect he was quite mistaken. Leclere afterward collected, during his journey in Yun-nan, several fossils which enabled Prof. Douville[264] to recognizetthe presence of the Middle Devonian and the upper Devonian in the Lou-nan district. Following this determination Leclere extended its application to many other districts The Lantenoi's mission[39] has done much to perfect our knowledge about the different stages of the Devonian in eastern Yun-nan. It verified, at numerous localities, the presence of either the Upper Devonian or the Middle Devonian, and even recognized with some doubt, the occurrence of the Lower Devonian. The recent research of Dr. Deprat has not only definitely proved the presence of the Lower Devonian in Yun-nan but has succeeded in establishing no less than 18 fossiliferous zones representing the whole sequence of the Devonian strata in the same region.

Devonian rocks occur in eastern Yun-nan in parallel narrow bands which extend in a N.N.E. direction. The main band runs along the margin of the Tie-tchen-ho basin in the shape of a **scarp**, and passes the towns of Lin-ngan and of Lou-leang. These bands are confined to a region which is limited, on the N.W. by the lakes of Cheng-kiang, Ning-chou, and Shi-ping-chou; on the S.E. by the broad Triassic basin. Outside this region in eastern Yun-nan, Devonian rocks have not been discovered, and they probably do not occur.

The Devonian rocks in this region are usually composed of sandy, shaly and argillaceo-calcareous deposits. The last mentioned predominates, pure limestone ~~are~~ being rare. Within an insignificant distance, a zone often changes its lithological character while it retains the same fauna.

The complete succession of the Devonian rocks is well exposed between the heights of Po-shi at Ta-ping-pou and the valley of the Tie-tchen-ho or the Pa-ta-ho. The sequence has been made out by Deprat as follows:-[13] (see section No. 57)

Upper Devonian.

(d 6 a. Scaly argillaceous limestone - - - - 40 m.
containing SD a 4 to SD a 11, SD c 1.

(d 6. Crinoidal gray limestone - - - - - - 40m.
containing SD a 12 to SD a 17.

(d 5 a. White encrinus limestone .- - - - - 100 m.
containing SD a 12 , SD a 17 to SD a 22.

(d 5 c. Compact limestone of rose colour . . 60 m.
containing SD d 1, SD e 1.

(d 5 b. Hard, scaly, light gray shale of
Lou-tchai-tchong and of Yi-leang - - 200 m.
containing SD a 20, SD a 23,
SD a 24, SD e 2, SD f 1, SD z 2,
SD z 3.

(d 5 a. Bright hard scaly shale with
alternating calcareous bands, the
individual shaly beds are usually
5 to 6 m thick. - - - - - - - - - - - -80 m.

(d 5. Black shaly limestone full of
fossils - - - - - - - - - - - - - - - 200 m.
the following species have been
identified:
SD a 21, SD a 18, SD a 19, SD a 26,
SD a 24, SD a 27, SD a 28, SD a 29,
SD c 1 to SD c 4.

Middle Devonian

(d 4 b. Nodular (rognonneux) shaly limestone
gray or black - - - - - - - - - - - - - - 260 m.
containing SD a 26, SD a 30 to SD a 39,
SD e 3, SD b 4 to SD b 6, SD d 3 to
SD c 5, SD c 6.

(d 4 a. Gray shaly limestone and shales - - - 135 m.
containing SD a 40, SD a 21, SD a 18,
SD a 26, SD c 6.

(d 4. Gray limestone - - - - - - - - - - - 35 m.
containing SD a 19, SD c 7.

(d 3 b. Dirty-gray shaly limestone with
polypiers (zone of Si-tche-yi) - - - 430 m.
containing SD a 18, SD a 20, SD a 40
to SD a 48, SD c 8 to SD c 18, SD c 5.

(d 3 a. Shaly "calcschists" with calceole - - 70 m.
containing SD c 19, SD c 9, SD c 10,
SD c 11, SD c 12, SD c 13, SD c 8,
SD c 15, SD c 17, SD c 5.

Middle Devonian.	d 3.	Purple shales and "calcschists" with polypiers - - - - - - - - - - - - - - - - 30 m. containing SD c 9, SD c 10, SD c 17, SD c 5.
Lower Devonian.	d 2 c.	Coarse-grained yellow sandstone (zone of He-mo) with bands of limestone - - - - - - - - - - - - - - - , - 250 m. containing SD g 1, SD a 49, SD b 7.
	d 2 b.	Hard gray limestone (zone of lan-nin-tsin) - 25 m.
	d 2 a.	Scaly yellow shales (zone of Pa-mao-tsen) -220 m.
	d 2.	Very hard black limestone - - - - - - - 10 m. containing SD a 40.
	d 1.	A series of fine-grained sandstone, soft shale, and red and green argillaceous limestone almost unfossiliferous (zone of Ki-tse-tchong) 600m. SD h 1. occasionally occurs.

In the district of Lou-nan, Deprat identified all the faunal zones described above except the lowest series, dl. Here the Devonian is unconformably underlain by the Cambrian on one side and separated from the Permain sandstone and conglomerate by a mighty fault on the other. The lithological sequence is as follows:-

Upper Devonian.	d 6 a.	Shaly and marly limestone with characteristic fossils.
	d 6.	Shaly and marly limestone with characteristic fossils.
	d 5 d.	Marly shale.
	d 5 b.	Calcareous shale.
	d 5, d 5 a.	limestone series more or less shaly.

Middle (d 4, d 4 a-b)
Devonian. ( ) limestone series more or less shaly.
(d 3, d 3 a-b)

(d 2 a. A series of clay shale and red and
(green shaly sandstone (zone of Pa-mao-tsen)
Lower (
Devonian. (d 2. Shale with Sieberella sieberi
(V. BUCH var. rectifrous B A R R.

(Unconformity)———————————————————

Cambrian Red clay shale with Redlichia chinensis.

At a locality 10 K.M. to the east of Tien-sen-kwan, near Lou-nan, Leclere found that the Devonian formation was overlain by carboniferous. He describes three lithological divisions. They are as follows:-[41]

Carboniferous

3. Alternating beds of shales and limestones extending from near Lou-nan to the border of the basin of Yun-nan-sen, and containing the following brachiopods.
SD a 53, SD a 23, SD a 10.

2. Thin bedded oolitic limestone resembling the globulitic Sinisian limestone as described by Richthofen.

1. Calcareous shale with well preserved fossils, among them there are SD a 53, SD a 9, SD a 12 etc.

At Ta-kwan-ting (lat. 27° 40'N. long. 103° 50'E.) N.E. Yun-nan, Richthofen obtained a Devonian fauna. The fossils were sold in the town of Ta-kwan-ting as curios. Richthofen was unable to find out the exact locality of occurrence. Presumably they were derived from the limestone mountains forming the S.E. border of the Red Basin of Su-chuan. The following species are among the identified forms:-[215]

SD a 42, SD a 8, SD a 40, SD a 26, SD a 61 to SD a 65, SD c 6.

At Yang-liu-shu, Ta-kwan-ting, in a coral limestone SD c 23, and SD c 1 have been discovered.[273]

Fron Ben-chou-tze and Ji-li-pu, Ta-kwan-ting, Yabe and Hayasaka obtained SD c 24.[273]

From these palaeontological data it can be inferred that Devonian rocks occur in the northeastern corner of Yun-nan.

Kwang-si.

At Tsien-kiang, (lat. 23° 30'N. long. 109° 40'E.) On the bank of the Si-kiang Leclere[42] observed calcareous shale containing "characteristic Devonian fossils" which overlies "pre-cambrian" rocks. In the district of Nan-ning (about lat. 22° 40'N. long. 108E.) in the same province, Leclere mentions a rose-red calcareous shale of "Devonian" age about 10 m thick overlying "pre-cambrian", and being overlain by a semi-crystalline limestone. This limestone attains a thickness more than 100 m, and forms the escarpment in the vicinity of Long-tcheou. Leclere remarks that similar semi-crystalline limestone is found at the base of the "carboniferous mountains" situated bewteen Long-tcheou and Lang-son.

T. Davidson[261] has described a Devonian fauna obtained from the province of Kwang-si, indicating the presence of Devonian formation in that province. It is to be regretted that the nature of the rock containing the fauna and the exact locality of occurrence are not known. The fauna consists of the follow -ing forms:-

SD c 5, SD a 24, SD a 54 to SD a 59.

Kwei-chou

At Lan-mou-tchang,[65] (lat. N. long. E.) half way between Hing-i-hien and Gan-shien, Monod noted that coal seam crop out on the slope of a hill. They are intercalated with sandy and pyritous shales. The coal bearing series is overlain by a limestone dipping 20° N.E. In the shales, Monod discovered many species of brachiopods which exclusively belong to the genus streptorhynchus. Fragments of phacops also occur in association with the brachiopods. Monod concludes that this coal bearing series is of Devonian age.

Southern Hu-nan.

In the Kiang-hwa district,[270] (lat. 25° 20'N. long. 111° 30'E.) Oelmichen collected a number of fossils from a black limestone. The material was examined by Frech who reports the presence of the following species:-

SD c 20 to SD c 22, SD a 60, SD d 13 to SD d 16.

Western China.

At Hoa-ling-pou[55] a place situated in the valley of Lou-kiang, (altitude about 2,466 m) near the N.W. border of the Red Basin of Su-chuan, (the writer is unable to locate the exact position of the place) Loczy collected a Devonian fauna which consists of the following species:-

SD b 10, SD a 38, SD a 33, SD a 36, SD a 65 to SD a 68, SD c 24 to SD c 28.

Near the source of the Kia-ling-kiang,[56] north of the Red Basin of Su-chuan, Loczy observed a series of clay shale underlying carboniferous rocks. The shale contains the follw following fauna:

SD a 37, SD a 69, SD a 70, SD b 11, SD c 29, SD g 2.

In journeying from Ning-kiang-tshou[91] (lat. 32° 50'N. long. 106° 25'E.) to the Red Basin of Su-chuan, along the valley of the Pai-yen-ho, Richthofen crossed a large anticline, the axial plane of which is overturned towards the south. He made out the succession of palaeozoic strata along his route. The whole sequence ranges from Silurian to Carboniferous as shown below:- (see sections No. 31, No. 32)

(e. White and yellow hard quartz-sandstone with a basal layer of calcareous shale, dips N20°W viz., the same as the underlying limestone.

Carboniferous?.) (f. Bituminous limestone containing black or white quartzite with brachiopods. Richthofen asserts that this series is doubtlessly the "Kohlenkalk" being identical with that occurring at Tshau-tien.

(Devonian?.) (g. Gray limestone and soft gray calcareous clay shale containing Atrypa reticularis.

ilurian?.) (h. Green slates (Schieferton) characterized by embedded nodules of limestone which contains species found in the underlying series i. Intercalated with the slates, are limestone bands of very variable nature, sometimes thick-bedded and sometimes thinly laminated, containing abundant fossils. each piece of the limestone shows organic structure. SD i 1, SD i 2, SD i 3, are the trilobites identified by Richthofen.

(i. Limestone and slates containing abundant corals, a few brachiopods and orthoceras but no trilobite. Among the corals there are SD c 30 to SD c 43.

(k. A thick series of green slates (Schieferton) with intercalated limestone strata containing brachiopods.

Silurian?

(l. Limestone with the intercalation of other kind of strata.
The upper part of the series consists of siliceous limestone about 15 feet thick, which is succeeded downwards by a slate, then a cherty conglomerate or cherty sandstone. The pebbles of the conglomerate are sometimes well-rounded and sometimes angular. Trilobites and brachiopods occur. The lower part of the series consists of an alternate of shale and limestone of varying thickness characterized by red limestone, red argillaceous limestone, andslightly crystalline limestone of greenish colour. In this lower part of the series SD a 71, to SD a 74, SD c 44, SD c 45, and crinoids occur.

(m. Slate (Schieferton) (= K)?

In connection with this section, a number of brachiopods other than those named above have been described. It is much to be regretted that Richthofen does not give the exact horizon or series from which they were collected. Presumably they are largely derived from the series h. The fauna consists of SD a 75 to SD a 80, SD a 1, SD a 18 etc. The genus Orthoceras is especially abundant, sometimes it forms a whole band of limestone. Crinoidal stems and the genus Encrinurus also frequently occur in association with the brachiopods in coral limestones.

During the journey from Tshau-tien (lat. 32° 40'N. long. 105° 40'E.) to Kwang-yuan-hsien (lat. 32° 25'N. long. 105° 40'E).

Richthofen observed important exposures of palaeozoic rocks. At the south of Lung-fang-kou, (see section No. 33) a limestone formation containing quartzite is exposed. From its lithological character Richthofen identified it as the "Kohlenkalk" which he saw elsewhere in the north. Under the "Kohlenkalk" there occurs a series of limestone and slate; on account of lithological resemblance Richthofen correlates them with the series h & i described above. The sequence is as follows:-

5. Red and green slate (Schieferton) with thin layers of limestone - - - - - - - - - - 1000 ft.
4. Well-bedded limestone - - - - - - - - - - - - 90 ft.
3. Green-red and yellow slate - - - - - - - - 200 ft.
2. Limestone bands prevailingly red and green 160 ft.
1. A series of indurated and contorted shale of red, brown and green colour with numerous layers of limestone.

Central China.

In the middle Yang-tze district, Blackwelder describes a shaly series which he calls Sin-tan formation.[177] This formation is believed by Blackwelder and Willis as Siluro-Devonian representative in central China, underlying the Ki-sin-ling limestone and underlying the Wu-shan limestone. The Sin-tan formation essentially consists of olive green massive shale with intercalated beds of reddish mudstones, quartzite and earthy limestone. The total thickness is estimated at 1800 ft in the vicinity of the Ta-ning-ho.

The upper part of the Sin-tan formation is exposed in the neighbourhood of Ta-ning-hsien (lat. 30° 42'N. long. 109° 40'E.) and at Wa-tze-ping, between the Ki-sin-ling and Chon-ping-hsien. It passes upwards into the overlying massive Wu-shan limestone by a series of transitional alternating beds of shales and limestones. At a place north of Tung-kuan-kou and south of Ta-miau-ssi, near Ta-ning-hsien, the thin shaly layers lying between beds of greenish-gray granular limestone, belonging to the uppermost portion of the Sin-tan series, have yielded a fauna of brachiopods and polyzoa. It consists of the following:-

SD f 2 to SD f 6, SD a 81 to SD a 84.

Crinoidal fragments, fish plate(?) and trilobitic remains (SD i 4) are also reported to occur in association with the forms mentioned above.

The lower part of the Sin-tan formation is exposed on the northern side of the Ki-sing-ling (lat. 31° 45'N. long. 109° 30'E.) where the Ki-sin-ling limestone lies overturned on the Sin-tan series. It is also exposed in the Wu-shan and I-chang gorges. The lower part of this series grades into the underlying Ki-sin-ling limestone by gradual change of lithology and no discordance of stratification. A layer of cherty conglomerate or "lydite" is taken as the base of the Sin-tan series.

S.E.China.

The lower Yang-tze valley.

About 3 miles from the city of Kiu-kiang, (lat. 29° 40'N. long. 116° 10'E.) in a gravel pit Kingsmill observed the edges of metamorphosed strata of blauish-grey limestone dipping vertically and striking W.S.W. i.e., parallel to the trend of the Lu-shan situated on the N.W. of the Po-yang lake. Some 15 miles west of the gravel pit limestone hills appear. The limestone exposed in these hills is not metamorphosed, and its lithology is distinctly different to the limestone exposed in the gravel pit. Kingsmill infers that the limestone exposed in the hills is probably unconformably underlain by the altered limestone exposed in the pit. He assigns Devonian age to the latter through comparing with the limestones observed by Bickmore at Ki-yang, on the river Siang-kiang, eastern Hu-nan. At Ki-yang Bickmore saw a limestone bearing close lithological resemblance to that forming the hills of Kiu-kiang. This limestone rests on the overturned edges of altered limestone strata; The latter is lithologically similar to the metamorphosed limestone exposed in the gravel pit of Kiu-kiang, and contains Terebratula? and Stringocepalus. Kingswell's own observation at the Tai-hu district (to be described presently) also tends to confirm that the altered limestone is probably of Devonian age.

In the Tung-kwan-shan (see section No.43) N.E. of

Ta-tung (about lat. 31°N. long. 118°E.) Richthofen saw a thick-bedded quartzitic sandstone with thin layers of soft sandy shale;[114] the shaly intercalation gradually disappears towards the lower part of the series. This sandstone is followed downwards by a dark gray limestone which becomes thin-bedded and highly siliceous towards the lower part of it. The stratigraphical relation between the sandstone and the limestone is not definitely known; they may be unconformable according to Richthofen. He assigns the sandstone to the Devonian.

In the Hsiau-hua-shan, southern An-hwei, Richthofen observed a series of sandstone underlying limestone. The strata dip N.W. which is also the direction of dip of the Sinisian strata exposed in the Ta-hua-shan further S.E. Richthofen gives the following sequence:-[26]

(Carboniferous?) 6. Gray limestone with much hornstone and intercalated marly and nodular layers. Crinoids and brachiopods occur. Richthofen remarks that this limestone strongly reminds him of the carboniferous limestone of Hsi-hsia-shan. (p 187)

(Devonian?.) 5. A series of sandstones.
- e. Sandstone.
- d. "Festes quartzite mit Verlust des Sandstein-Gefüger".
- c. Sandy conglomerate with quartzite pebbles
- b. Firm, thick-bedded sandstone of dark green colour.
- a. Stratified marl and sandy marl.

(Interruption for a distance of 3 K.M. by the lake)

4. Heavily bedded limestone etc (see p 126)

In dealing with the Sinisian system, the occurrence of a graptolitic shale in the Lun-shan near Cheng-kiang, (lat. 32° 10'N. long. 119° 20'E.) has already been described. (see p 128) On the Southeastern side of the hill, the bedded rocks are hidden from sight. Further S.E. there rises a second hill, the Kau-li-shan, (see section No 45) which is the southwestern continuation of the Tshu-shan. On the northwestern flank of the Kau-li-shan, well-bedded rocks again makes appearance dipping in the same direction as the Sinisian strata of the Lun-shan, i.e., towards S.E. The horizontal distance of the interruption of exposure between the two hills to roughly 7000 to 8000 ft which corresponds to a vertical thickness of strata of approximately 5000 ft, assuming that the dip and succession of the hidden beds are as regular as those exposed in the Kau-li-shan and the Lun-shan. In the lower part of the N.W. flank of the Kau-li-shan, fine-grained, hard splintery quartzite of apple green colour is exposed. This quartzite is overlain by indurated sandstone and conglomerate, attaining a thickness of 1200 ft and forming the bulk of the hill. 115 The conglomerate is largely composed of quartz pebbles. To the S.E. of the Kau-li-shan, these coarse deposits are followed by the limestone (3), coal bearing series(4) , and limestone (5). These will be described later (p 190). Richthofen regards the sandstone and conglomerate as Devonian formation.

In the hill of Hwa-shan, 116 (lat. 32° 5'N. long. 119° 25'E.) half way bewteen Nan-king and Cheng-kiang, Richthofen observed a sequence of rocks to which he tentatively assigns

Devonian age. The sequence is as follows:-

3. Red slate.

2. Dolomite.

1. Quartzite.

In the vicinity of Nan-king, Kingsmill has made out the following sequence:-[36]

6. Fine-grained yellow sandstone, finely laminated, capping Tsing-liang and other hills lying to the east of the city; dip 10° to 15° E.

5. Conglomerate composed of waterworn pebbles of quartz and limestone. The material becomes finer toward the top and the beds dip 15° to 30° E.

4. Coarse and granular, yellow and white quartzose sandstone forming low hill outside the western wall of the city; striking near E - W, dipping at high angles either N. or S.

3. Subcrystalline dolomite.

2. Gritty slates much contorted striking N - S and dipping vertical.

1. Tze-chin-shan quartz much fractured, no trace of bedding.

Kingsmill states that 1, 2, and 3 in the sequence cited above are probably of Devonian age.

From a light bluish-gray crystalline dolomitic limestone exposed in the Tung-ting-shan and the Si-tung-ting-shan in the lake of Tai-hu,[36] southern Kiang-su, Kingsmill collected a few species of corals and brachiopods of Devonian aspect. In a quarry N.W. of Hoo-chow, near the Tai-hu lake, the same crystalline limestone rests upon a quartzitic sandstone which Kingsmill calls the "Tung-ting grit"

Plant remains, such as ferns and conifers, occur in the upper part of the Tung-ting grit.

(III) Correlation.

<u>In Eastern Yun-nan,</u> the classification of the Silurian and the Devonian rocks based on palaeontological data, has been exhaustively described in pp 141 to 147 . It is unnecessary to reiterate the evidence proving the age of the rocks. The Ta-kwan-ting fauna collected by Richthofen (p 148) may not have been derived from a single zone, but as a whole, it is comparable with the Middle Devonian; The faunas of Yang-liu-shu and of Ben-chow-tze also belong to the same stage.

<u>In the province of Kwang-si,</u> Devonian rocks doubtlessly occur. The fauna described by T.Davidson (p 148) rather suggests upper or Middle Devonian age because of the presence of Aulopora tubaeformis and productella subaculeatus.

<u>In the province of Hu-nan,</u> the presence of marine Devonian formation is indicated by the Kiang-hwa fauna (p 149) which, according to Frech, is comparable with the upper stringocephalus limestone of Europe. The presence of the species Spirifer aperturatus SCHLOTH var. cuspidata suggests to Frech that the lower part of the same limestone is probably also represented in the Kiang-hwa district.[270]

<u>In western China,</u> Loczy collected two faunas at Hoa-ling-pu and Kia-ling-kiang. (p 150) They are comparable with the middle Devonian of eastern Yun-nan according to Deprat.

In Richthofen's Ning-kiang-tschou section, (p 150) both Silurian and Devonian are present. The series (e) is regarded by Kayser as probably belonging to the Middle Silurian or upper Llandovery. The series (i) with the rich fauna of polypiers and the characteristic brachiopod Orthis bouchardii is correlated by Deprat with the Silurian or Gothlandian in eastern Yun-nan, which also contains Orthis bouchardii; further he compares the formations containing these fossils in China with the graptolitic shale and Encrinus limestone of Burma, to all these time equivalents he assigns Wenlock Age. The series (h) is regarded by Kayser as representing Wenlock, while Deprat correlates it with the Ordovician strata in eastern Yun-nan. If Richthofen's section is in the right order, Deprat's correlation would be obviously an erroneous one. (Presumably he did not study the detail of Richthofen's section) It is however not surprising for Deprat to make such a correlation, for the presence of Asaphus and Trinucleus would certainly suggest Ordovician rather than Silurian. The series (g) is regarded by Richthofen as Devonian on account of the presence of Atrypa reticularis.

<u>In Central China</u>, the Sin-tan formation (p 152) is underlain by the Ki-sin-ling limestone of middle Ordovician age, and is overlain by the Wu-shan limestone of either upper carboniferous or lower carboniferous age. That is to say the Sin-tan series is younger than Middle Ordovician and older than Lower or Upper Carboniferous. The fauna that has been obtained from the upper part of the series (p 153)

does not tell us the exact age of the containing rock. The Bryozoans or Polyzoans are considered by Ulrich and Bassler as being of Lower Carboniferous age,[178] (Mississippian) the brachiopods, however, suggests to Girty[179] an earlier period .— . Devonian or possibly Silurian. The association indicates earlier appearance of the Bryozoans or later range of the Brachiopods. Regarding the Wu-shan limestone which overlies the Sin-tan series as Lower Carboniferous, Blackwelder deduces the age of the former in the following way:-[180]

From the Wu-shan limestone at Tung-kwan-kou, about 1,200 ft above the fossiliferous horizon of the Sin-tan series, upper carboniferous forms were collected; furthermore fossils obtained on the Ta-ning-ho, from the basal layer of the Wu-shan limestone are also of upper carboniferous age. It is therefore no part of the great limestone can be assigned to the lower carboniferous. Thus there is no more than a few feet of shale between a definite upper carboniferous horizon and a doubtful one, which is either lower carboniferous or earlier. Blackwelder states that he does not think that it can be much earlier therefore assigns it to the Lower Carboniferous, and hence regards the underlying 1800 ft of the Sin-tan shale as representative of Silurian and Devonian formation in Central China.

It is a remarkable fact that the cherty conglomerate which forms the base of the Sin-tan series (p 153) is also mentioned by Richthofen in his Ning-kiang-tschou section. (p 151)

It would be too hasty, however, to state at present that the said cherty conglomerates belong to one and the same geological formation.

In the lower Yang-tze valley, the stratigraphical data are too uncertain to permit a definite correlation of the Devonian and Silurian rocks. From the observations recorded in pp 154 to 158, it appears that the Devonian probably consists of two series of rocks of entirely different lithological type - - - - the crystalline dolomitic limestone, and the quartzite and conglomerate. Richthofen's observation at Hwa-shan (p 156) and Kingsmill's observation near the Tai-hu- lake (p 157) seem to agree in showing that the dolomitic limestone overlies the conglomerate.

L I S T No 2.

FOSSILS FOUND IN SILURIAN-DEVONIAN ROCKS IN CHINA.

Note The reference no. of each species is only used in this thesis for convenience.

Reference No.	Names	Stratigraphical position: Silurian	Lower Devonian	Middle Devonian	Upper Devonian	Originally described in — (See bibliography)	Mentioned in this thesis in p. —
	(a) BRACHIOPODA						
SDaI	Orthis bouchardii DAVIDS.	x					
SDa2	Lingula loulanensis MANSUY	x					
SDa3	Spirifer tonkinensis		x				
SDa4	Spirifer tenticulum VERN				x		
SDa5	Spirifer curvatus SCHL				x		
SDa6	Atrypa douvillei MANSUY				x		
SDa7	Atrypa arimaspus EICHW.				x		
SDa8	Atrypa desquamata SOW.				x		
SDa9	Rhynchonella hoati VERN. & KAYS.				x		
SDaI0	Rhynchonella letiensis GOSSELET				x		
SDaII	Rhynchonella gigantea MANSUY				x		
SDaI2	Rhynchonella (pugnox) pugnos MART.				x		
SDaI3	Rhynchonella (camarotaechia) convexa MANSUY.				x		
SDaI4	Spirifer verneuili MURCH. var. yunnanensis MANSUY				x		
SDaI5	Atrypa bodini MANSUY						
SDaI6	Anastrophia proxima MANSUY				x		
SDaI7	Spirifer curvatus V. BUCH				x		

SDa18	Atrypa reticularis LINNE.		x	x		
SDa19	Atrypa aspera DALM.		x	x		
SDa20	Athyris concentrica v. BUCH.		x	x		
SDa21	Orthis striatula D'ORB.		x	x		
SDa22	Productus sp.			x		
SDa23	Rhynchonella omaliusi GASSELET.			x		
SDa24	Productella subaculeata MURCH.			x		
SDa25	Leiorhynchus deprati MANSUY.			x		
SDa26	Strophalosia productoides MURCH.		x	x		
SDa27	Rhynchonella productoides KAYS. var. long-tung-peensis KAYS.			x		
SDa28	Streptorhynchus umbraculum SCHL.			x		
SDa29	Orthothetes crenistria PHILL.			x		
SDa30	Stringocephalus burtini DEFR.		x			
SDa31	Uncites gryphus SCHL.		x			
SDa32	Cyrtina heteroclyta DEFR.		x			
SDa33	Spirifer undiferous ROEMER.		x			
SDa34	Spirifer thetidis KAYS.		x			
SDa35	Spiriferina cristata SCHLOTH var. octoplicata SOW.		x			
SDa36	Chonetes orientalis v. LOCZY.		x			
SDa37	Waldheimia whidbornei DAV.		x			
SDa38	Camarophoria ss-eu-tchoanensis LOCZY.		x			
SDa39	Athyris concentrica M'COY.		x			
SDa40	Conchidium (Sieberella) galetum DALM.		x			
SDa41	Spirifer concentricus SCHNUR.		x			
SDa42	Nucleospira takwanensis KAYS.		x			

SDa43	Plectambonites rohmboidatis PHIL.		x	
SDa44	Dielasma curvirostris MANSUY.		x	
SDa45	Retzia yileangensis MANSUY.		x	
SDa46	Meristella flayellei MANSUY.		x	
SDa47	Megalanteris archiaci DE VERB.		x	
SDa48	Orthis striatula DEFR.		x	
SDa49	Meristella sp.	x		
SDa50	Spirifer jouberti OEHL. & DAV.	x		
SDa5I	Retzia plicata MANSUY.	x		
SDa52	Leiorhynchus sp.	x		
SDa53	Atrypa explanata SCHL.			x
SDa54	Spirifer disjunctus SOW.		?	?
SDa55	Spirifer murchisoniana KONINCK sp.		?	?
SDa56	Rhynchonella hamburii DAVIDSON.		?	?
SDa57	Cronia obsoleta GOLDF.		?	?
SDa58	Spirobis omphalodes ?		?	?
SDa59	Cornulites. epithonia ? GOLDF. sp.		?	?
SDa60	Spirifer aperturatus SCHLOTH. var. cuspidata D'ARCH & VERN.		x	
SDa6I	Spirifer undiferous var. takiensis		x	
SDa62	Orthis striata		x	
SDa63	Rhynchonella parallipipeda		x	
SDa64	Rhynchonella yunnanensis		x	
SDa65	Meristella plebeia		x	
SDa66	Rhynchonella cf. elliptica SCHNUR.		x	
SDa67	Spirifer cf. elegans STEIN.		x	
SDa68	Pentamerus galeatus DALM.		x	

SDa69	Spirifer aperturatus SCHL.			?			
SDa70	Pentamerus brevirostris PHILL.			?			
SDa71	Orthis calligramma DALM.	x					
SDa72	Spirifer radiatus SOW.	x					
SDa73	Leptaena sericea SOW.	x					
SDa74	Strophomena corrugatella DAV. ?	x					
SDa75	Orthis kiautschangpensis n. sp.						
SDa76	Spirifer elevatus DALM.						
SDa77	Spirifer interlineatus SOW.						
SDa78	Rhynchonella bovealis var. sinensis						
SDa79	Merista tumida DALM.						
SDa80	Strophomena shonnsuenensis n. sp.						
SDa81	Dalmanella (?) sp.						
SDa82	Schuchertella (?) sp.						
SDa83	Spirifer (?) sp.						
SDa84	Rhychonella (?) sp.						
	(b) LAMELLIBRANCHIA						
SDb1	Modiomorpha lavali MANSUY.	x					
SDb2	Palaconcilis triangularis MANSUY.	x					
SDb3	Cythere sp.	x					
SDb4	Cardiola migrans BARR.			x			
SDb5	Modiomorpha duponti MANSUY.			x			
SDb6	Megalodon cucullatus SOW.			x			

SDb7	Actinopteria deprati MANSUY.		x				
SDb8	Pterinea lineata GOLDF.		x				
SDb9	Limoptera inopinata MANSUY.		x				
SDbIO	Actinopteria ? densiradiata n. sp. LOCZY. . . .			x.			
SDbII	Cypricardinia scalaris PHILL.			?			
	(c) ANTHOZOA						
SDcI	Cyathophyllum douvillei FRECH.			?	x		
SDc2	Alveolites suborbicularis LINK.				x		
SDc3	Alveolites subequalis M. E. & H.				x		
SDc4	Cyathophyllum hexagonum MICH.				x		
SDc5	Aulopora tubaeformis GOLDF.			x			
SDc6	Aulopora repens KNORR.			x			
SDc7	Cyathophyllum caespitosum GOLDF.			x			
SDc8	Metriophyllum poshiensis MANSUY.			x			
SDc9	Cyathophyllum roemeri M. E. & H.			x			
SDcIO	Cyathophyllum helianthoides GOLDF.			x			
SDcII	Cyathophyllum obtortum M. E. & H.			x			
SDcI2	Cyathophyllum vesculosum PHILL.			x			
SDcI3	Cyathophyllum americunum M. E. & H.			x			
SDcI4	Endophyllum yunnanensis MANSUY.			x			
SDcI5	Smithia hennahi M. E. & H.			x			
SDcI6	Favosites subregularis MANSUY.			x			
SDcI7	Favosites sphaericus HALL.			x			
SDcI8	Pachypora polygonalis GOLDF.			x			

SDcI9	Calceola sandilina LINK.			x			
SDc20	Syringopora sp.			x			
SDc2I	Favosites polymorphus GOLDF.			x			
SDc22	Endophyllum acanthicum FRECH.			x			
SDc23	Favosites asteriscus FRECH.			x			
SDc24	Favosites goldfussi M. EDWARDS & HAIME.			x			
SDc24'	Favosites goldfussi D'ORB.			x			
SDc25	Favosites asteriscus FRECH. n. sp.			x			
SDc26	Favosites cervicornis BLAINV.			x			
SDc27	Alveolites reticulatus STEIN.			x			
SDc28	Cyathophyllum loczyi FRECH n. sp.			x			
SDc29	Favosites reticulatus BLAINV. sp.			?			
SDc30	Somphopora daedalea n. sp. LINDS.						
SDc3I	Favosites forbesi E.H.	x					
SDc32	Favosites fibrosus GOLDF.	x					
SDc33	Heliolites interstinctus LINDS.	x					
SDc34	Plasmopora tubulata LONSD,	x					
SDc35	Halysites catenularia LINDS.	x					
SDc36	Amplexus distans n. sp. LINDS.	x					
SDc37	Amplexus appendiculatus n. sp. LINDS.	x					
SDc38	Cyathophyllum angustum LONSD.	x					
SDc39	Cyathophyllum densum n. sp. LINDS.	x					
SDc40	Ptychophyllum richthofeni n. sp. LINDS.	x					
SDc4I	Ptychophyllum cyathiforme n. sp. LINDS.	x					
SDc42	Platyphyllum sinensis n. sp. LINDS.	x					
SDc43	Cystiphyllum cylindricum LONSD.	x					

SDc44	Ceriaster calamites n. sp. KAYS.	x					
SDc45	Amplexus vidurs n. sp. KAYS.	x					
	(d) GASTROPODA						
SDd1	Styliola sp.				x		
SDd2	Macrochilina arculata SCHLOTH.			x			
SDd3	Natica antiqua GOLDF.			x			
SDd4	Murchisonia loxonemoides WHIDB.			x			
SDd5	Murchisonia bigranulosa VERN.			x			
SDd6	Murchisonia angulata PHILL.			x			
SDd7	Murchisonia angulata PHILL. var conoidea MANSUY.			x			
SDd8	Murchisonia margarita WHIDB.			x			
SDd9	Bellerophon striatus FERUSSAC & VERN.			x			
SDd10	Pleurotomaria delphinuloides SCHOLTH.			x			
SDd11	Pleurotomaria subimbricata M'COY.			x			
SDd12	Tentaculites irregularis MANSUY.		x				
SDd13	Bellerophon striatus FRECH.			x			
SDd14	Bellerophon memoria kokeni FRECH.			x			
SDd15	Pleurotomaria delphinuloides D'ARCH. var. subcostata SCHLTH.			x			
SDd16	Pleurotomaria delphinuloides D'ARCH. var. nov. bathyschistus.			x			

	(e) CEPHALOPODA						
SDeI	Paradoceras globosum MUNST.				x		
SDe2	Orthoceras sp.				x		
SDe3	Cyrtoceras (Kophinoceras) ornatum GOLDF. . .			x			
	(f) BRYOZOA						
SDfI	Favositella columnaris MANSUY.				x		
SDf2	Fistulipora willisiana GIRTY						
SDf3	Fistulipora sp.						
SDf4	Leioclema sp.						
SDf5	Taeniodictya (?) sp.						
SDf6	Fenestella (?) sp.						
	(g) HYDRAZOA						
SDgI	Stromatopora		x				
SDg2	Stromatopora concentrica GOLDF.			?			
	(h) OSTRACODA						
SDhI	Cypridinia (Entomis) sp.		x				

	(i) TRILOBITA						
SDiI	Asaphus sp.	?					
SDi2	Calymene sp.	?					
SDi3	Trinucleus richthofeni n. sp.	?					
SDi4	Proctus (?) sp.						
	(z) FLORA						
SDzI	Sphenophyllum undt.	x					
SDz2	Lepidodendron sp.				x		
SDz3	Sigillaria sp.				x		

CARBONIFEROUS-PERMIAN...

INCLUDING

THE SHANSIAN SYSTEM.

(1) GENERAL REMARKS.

The upper palaeozoic rocks in China are well-developed, widely distributed, but have not been systematically classified except in Eastern Yun-nan where the recent research of Dr. Deprat has not only enabled him to differentiate the carboniferous from the permian, but to bring forward sufficient stratigraphical data to subdivide each system into three divisions. Elsewhere in China the distribution and the nature of the Carboniferous rocks are comparatively better understood than those of the Permian. ~~The pre~~sence of the former in Northern China ~~has been def~~in~~ite~~ly known since Pumpelly's time, who ~~discovered plant~~ remains which are also present in the coal measure~~s in~~ Europe and North America.

In Northern China, viz., in the provinces of Shan-tung, Chi-li, Shan-si, Shen-si, Ho-nan and including Southern Manchuria, the development of the upper palaeozoic rocks is essentially similar. They rest unconformably upon the Sinisian limestone to which miners often give a misleading name

"Carboniferous limestone" or "Mountain limestone". Richthofen, too, erroneously called the upper Sinisian limestone in Shan-tung, "Kohlenkalk" because of the fact that it is immediately overlain by the coal bearing upper palaeozoic group. The unconformity between the upper Sinisian and the upper palaeozoic in Northern China is usually not shown by discordance of bedding; but in the province of Shan-si, the Sinisian limestone underlying the upper palaeozoic group generally exhibits a rubbly appearance near the junction between the two, and it frequently shows highly iron-stained caverns, fissures, cracks filled up by shaly material clearly of secondary origin. Although these phenomena may be due to the work of the percolating water and therefore may not necessarily bear witness on the stratigraphical break, the hiatus of the life-sequence proves the existence of an unconformity beyond any doubt. The top of the Sinisian yields Ordovician forms, while the overlying upper palaeozoic group contains carboniferous fauna and in some cases Permian plant remains. This unconformity in northern China has been carefully described by Richthofen, Lorenz, Blackwelder and others. No further emphasis is needed.

In summarizing the observations made in the province of Shan-si, Blackwelder introduced the phrase "Shansian system" to express the upper palaeozoic coal bearing rocks in that province. Since the development of the upper palaeozoic group is essentially the same all over Northern China as already stated, the writer thinks it justifiable ~~proposes~~ to extend the application of the phrase "Shansian System", as Blackwelder seems to have done, to the complete upper palaeozoic group of rocks and to the whole area of Northern China.

The Shansian system thus defined largely consists of sandstones and shales with occasional bands of bituminous or carbonaceous marine limestones lying near the base or ~~at~~ in the base of the system. Intercalated with the shales and sandstones and sometimes limestones are coal seams of excellent quality. The upper part of the coal bearing series generally merges into a massive barren sandstone, the age of which has not been definitely determined; but it probably extends to the beginning of the Triassic time or possibly later. Between this barren sandstone and the top of the coal bearing series, no stratigraphical breaks have been discovered. The sandstone is interbedded with basaltic lava in the province of Shan-tung.

The Shansian rocks usually occur in synclines, or on the top of plateaus and sometimes on the down-throw side of large normal faults. They are often laid bare on the surface of the ground but occasionally covered by younger deposits.

In N.W.China, viz., in the Nan-shan region and the adjoining districts, the scattered observations made by Loczy, Obrutchov & Futterer have definitely proved the presence of marine carboniferous formation as well as coal bearing carboniferous rocks. But the stratigraphical details of the upper palaeozoic group in this region have not been systematically described by any geologist.

In Central China, in the Tsing-ling range, Richthofen has shown that marine carboniferous with seams of coals are involved in the folding. With regard to the Permian nothing has been said by the same author.

In the middle Yang-tze district, Richthofen, Abendanon, Blackwelder have described a massive limestone formation of Carboniferous age, with occasional anthracite. It conformably succeeds the underlying Siluro-Devonian rocks; (the Sin-tan formation) and it is believed to be unconformably overlain by the "Permo-Mesozoic strata", but the unconformable junction has not been observed.

In the lower Yang-tze valley, the lower part of the Carboniferous is generally composed of marine limestone, massive and often bituminous, the upper part of the carboniferous usually consists of coarse sediments with intercalated coal seams, the Permo-carboniferous and Permian are sometimes represented by Fusulina limestone and sometimes by pyroclastic or other volcanic products together with occasional coal seams. It is not clear as to whether or not the lower carboniferous, upper carbomiferous and the permian constitute a conformable sequence, and as to how the lower carboniferous is underlain by the Devonian and the Permian is overlain by the ? Mesozoic in this region.

In the province of Hu-nan, the presence of coal bearing Permo-Mesozoic rocks is suggested by a peculiar lamellibranch fauna which was discovered in one of the anthracite fields in that province.

In South-Western China, the occurrence of carboniferous rocks was first definitely announced by Douville who identified a number of species contained in a Foraminiferal limestone. Subsequent research of Lantenois enabled us to understand that the Uralian or upper carboniferous formation attains wide development in Eastern Yun-nan, but the same author created much doubt as to the presence of the Middle Carboniferous or Moscovian and Lower Carboniferous or Dinantian in the said region. Lantenois observed that the upper carboniferous limestone sometimes rests upon Middle Devonian, sometimes Lower Devonian and even Cambrian. These observations led him to assume the existence of a stratigraphical break between the Upper Devonian and the Upper Carboniferous, and the absence of the Lower Carboniferous rocks in Eastern Yun-nan. In the years 1909-10, the exhaustive search of Deprat and Mansuy resulted in the discovery of the lower and the middle carboniferous formations, the former being conformably underlain by the Devonian, and conformably overlain by the Middle Carboniferous. Thus the unconformity between the Upper Carboniferous and the Middle Carboniferous in Eastern Yun-nan has been definitely established.

According to Deprat, the Upper Carboniferous passes upwards into the Permian in perfect conformity in the region of Eastern Yun-nan, and there the Permian rocks are divisible into three series:- (1) A massive limestone is unconformably overlain by (2) a thick conglomerate which is succeeded upwards by (3) sandstones and interbedded andesitic and basaltic lava. These three lithological divisions do not correspond with the chronological divisions of the Permian period. The formation of the lower limestone occupied the whole of the Lower and the Middle Permian period. The earth movement which has given rise to the unconformity probably took place at the end of the Middle Permian or the early Upper Permian time.

The junction between the Lower Trias and the Upper Permian is not well exposed in eastern Yun-nan as the result of great disturbance experienced by the Triassic and the older strata. In one instance however Deprat observed erosion unconformity between the Lowest Trias and the Uppermost Permian.

Fossils that have been found in the Lower Carboniferous in China are chiefly brachiopods and corals. Among the characteristic species we may mention productus striata, P. cora, P. undatus, spirifer subconicus, Spirifer (Martinia) glabra, zaphrentis beyrichi, Z. spinulosa, Syringopora ramulosa, Michelina favosa, Lonsdaleia floriformis etc.

The Middle and the Upper Carboniferous fauna is characterized by abundant Foraminifera. The well-known species are Tetrataxis conica, Fusulina regularis, F. brevicula, F. multisepta, Doliolina aliciae, n. sp., Schwagerina princeps, Neoschwagerina craticulifera. Among the Brachiopods, the following species are considered to be fairly characteristic. Spirifer mosquensis, productus indicus, P.longispinus, P.lineatus, P. subplicatilis, etc. The genus phillipsia, the last representative of trilobites, is present in the Upper Carboniferous fauna of China.

A flora has been discovered from the coal bearing rocks in the northern part of the country. It consists of Lepidodendron, Sigillaria, Cordaites, Sphenopteris, Pecopteris, Taeniopteris, Neuropteris, etc. Some of the species occur in the coal measures of Europe and North America, others are only known in the Permian of Europe. It is thought by the writer that they probably represent the permo-carboniferous period.

The Lower Permian fauna is, as in the case of the middle and the upper carboniferous, largely foraminiferal; the Brachiopods spirifer blassi, camarophoria globulina, Martiniopsis inflata, productus gratiosus are thought to be the characteristic forms of the period.

The Middle Permian fauna is characterized by Doliolina lepida, Schwagerina verbecki, S.craticulifera etc. The Upper Permian fauna is very little known in China. It appears to be largely represented by Gastropods and Lamellibranchs.

(II) FIELD OBSERVATIONS.

(The full names of the fossils mentioned under this heading are found in List No.3).

S.W. CHINA.

EASTERN YUN-NAN

The upper palaeozoic rocks are well developed in this region; both the carboniferous and the permian are divisible into three stages, viz., upper, middle and lower.

A. CARBONIFEROUS.[14]

c.	Upper Carboniferous ~~(unconformity)~~ (unconformity)	(Foraminiferal limestone with (occasional basal conglomerate.	
b.	Middle Carboniferous	(Upper part (Lower part	Limestone. Sandstone.
a.	Lower Carboniferous	(Upper part (Middle part (Base	Limestone. Shale. Sandstone.

a. LOWER CARBONIFEROUS. The lower carboniferous rocks in Eastern Yun-nan are exposed at Hoa-Keuon and extends towards Mi-leu where they appear underneath the Upper Carboniferous.[14] They are also preserved in the vicinity of Po-shi owing to the presence of a fault. Deprat has made out the sequence of the lower carboniferous as follows:-

hV. Limestone of Tou-mou-nyi with CP b1, CP.b2.

h IV. Black limestone of Hoa-heuon with CP b3, CP.b4.

h III Yellow marly shale of Hoa-keuon with C.P.b5.

h II (h II b. "Calcschist" of Tien-sen-kouang with CP b 6.
(h II a. Marly shale of Tien-sen-Koung and Peu-Kiao with CP b7.

H I (Mottled sandstone and marl of Hoang-i-tien with CP b8.

This sequence is nowhere found complete. Sometimes the lower zones (h I, h II) are thrust over the Cambrian as in the districts of Yi-leang, Yi-long and Tou-mou-yi; and sometimes the middle zone (h III) is overfolded, and lies upon upper Carboniferous rocks as in the case of Hoa-Keuon, N.N.W. of Mi-leu-hsien. The zone (h V) is only observed by Deprat in the heights near the Blue River (Kin-sha-Kiang?).

b. Middle Carboniferous. The Middle Carboniferous comprises a mighty sequence of rocks in Eastern Yun-nan. They are exposed in the district of Tie-tchen-ho, and to the north of Yun-nan-fu. The strata are often broken up by faulting and thrusting. Deprat makes out the complete Middle Carboniferous sequence in Eastern Yun-nan as follows:-

h 2 Limestone of Lo-a-tien.

h 1 Limestone of Shouei-tang with a rich fauna of gastropods and others including the following species:-
CPc2 to CPc10, CPb16 to CPb 18, CPe 2, CPf2, CPf3, CPg1, CPg2, CPg3.

h,, A series of sandstone with coal and limestone with CPb15.

h,b Upper sandstone (The zone of Lao-na-tong)

h,a Limestone of Sha-tchong.

h (Lower sandstone (The zone of Ie-ma-tchoung)
(Basal conglomerate of Sin-tchai.

At Shouei-tang, west of Tie-tchen-ho, Deprat found a carboniferous syncline bounded by two mighty faults, i.e., the fault of Shouei-tang and the fracture of the lake Iangtsong. (see section No 5b). On the western side of the syncline the Cambrian formation with Redlichia chinesis makes appearance. This Carboniferous syncline consists of the following sequence of strata:-

Upper Carboniferous	h 5		Light gray limestone with CP b 16, CP a 5.	
	h 4		Dark gray limestone with CPa 6.	
	h 3a		Gray limestone with CP a 7.	
	h 3		Limestone with CP a 8.	
Middle Carboniferous	h 2		Gray limestone of Shouei-tang with Gastropods	100 m.
	h 1		Gray limestone (The zone of Lo-a-tien). . . .	80 m.
	h,,	17.	Light gray limestone with polypiers . . .	120 m.
		16.	White quartzitic sandstone	2 m
		15.	Coal.	1 m
		14.	White quartzitic sandstone	2 m
		13.	Hard green shale.	1 m
		12.	Dolomitic limestone	100 m
	h,b	11.	Fine-grained hard sandstone of red colour	12 m
		10.	"Labradorite".	18 m
		9.	Largely red arkose sandstone	10 m
		8.	Fine, compact and homogeneous red sandstone.	20 m
		7.	Conglomerate with small pebbles.	10 m
		6.	Fine & compact red sandstone.	15 m
		5.	Well-bedded massive red sandstone . . .	40 m
		4.	Conglomerate with small angular fragments	40 m
		3.	Red sandy grits.	30 m
		2.	Hard green marlstone	5 m
		1.	Micaceous red sandstone.	150 m.

Similar sequence of the Middle Carboniferous rocks up to the zone (h,,) is exposed in the district of Lou-nan, north of Yun-nan-fu, and it is overlain by bedded Permian basalt.

c. UPPER CARBONIFEROUS. At a number of localities in Eastern Yun-nan, Deprat has recognised an important stratigraphical break between the Shouei-tang limestone (h2) and the limestone containing Fusulina brevicula. The break is undoubtedly due to orogenic movement at the end of the Middle Carboniferous time, which was accompanied by vigorous erosion resulting in the removal of the Spirifer mosquensis limestone, the Shouei-tang and the Lo-a-tien limestone on the east of the Tie-tchen-ho and other localities; while to the west of the Tie-tchen-ho and in the region surrounded by the lakesof Tang-tsong, Eul-long-si-chou, Iang-lin, instead of erosion the period ~~is~~ has represented by the deposition of the zone (h3) and its ~~out~~ overlying strata. For this reason, Deprat regards the zone (h3) with Fusulina brevicula as the base of the Upper Carboniferous.

After a careful study of the protozoa found in the Upper Carboniferous rocks in eastern Yun-nan, Deprat has succeeded in establishing the following palaeontological zones:-

Upper Carboniferous (Limestone about 800 m.thick)

h 9 a.	Neoschwagerina multicircumvoluta n. sp.
h 9.	Neoschwagerina craticulifera Schwag.
h 8.	Schwagerina princeps Ehrenb.
H 7 a.	Fusulina incisa Schellw.
h 7.	Fusulina multisepta schellw and Doliolinas alicial n.sp.
h 6.	Doliolina claudiae n.sp. and Fusulinellas.
h 5.	Productus cf compressus waagen.
h 4.	Fusulina kattaensis schwag.
h 3 a.	Fusulina tcheng-Kiangensis n.sp. & Fusulina regularis schellw.
h 3	Fusulina brevicula schwag. & Fusulina regularis schellw.

As stated in the previous paragraphs, although these zones are represented by sediment to the west of the Tie-tchen-ho, to the east of the same river, some of the lower zones are frequently missing: e.g. in the district of Mi-leu, the zone (h 7) forms the base of the Upper Carboniferous; and in the district of Tou-nan, the lowest zone is (h 6).

Between Lao-yun and Wou-lou-si-shou, about 10 km. to the north of the lake Tsin-shouei-tang, Deprat observed the following sequence:-

Upper Permian	(Massive conglomerate more than	150 m.
	(Sandstone. . . . . about	10 m.
(Unconformity) ————		
Upper Carboniferous	(h 7 a. Limestone with C P a 10, C P a 9.	
	(h 7 Sandstone. . . . about	10 m.
	(Conglomerate . . "	10 m.
	((With pebbles of Devonian limestone).	
(Unconformity) ————		
Devonian	Stringocephalus limestone.	

A large anticline exists between Tien-sen-kouang and the plateau lying to the west of Ho-mo-Tchan the higher zones of the Upper Carboniferous are well-exposed on both sides of the anticlinal axis. The E.S.E. limb is composed of the following:-

Permian	r I	Limestone with CP b 20.
Upper Carboniferous	(h 9 a	Limestone with C.P.a 15.
	(h 9	Limestone with CP a 14.
	(h 8	Limestone with CP a 13, CP a 16.
(Unconformity) ————		
Lower carboniferous	h II, h II a	shale.

B. PERMIAN.[15]

c. Upper Permian. (Bedded andesitic & basaltic lava which is (followed downwards by sandstone and conglom-(erate.

(Unconformity) ———————————————

b. Middle Permian. (Tow facies are recognizable: In the southern (part of the region, the prevalent rock is a (white limestone; while in the northern part (of it, i.e., in the vicinity of the Blue (River, the Middle Permian is usually (represented by bluish sandy deposits.

a. Lower Permian. Limestone

a. LOWER PERMIAN. According to Deprat, the Lower Permian limestone is in perfect conformity with the Upper Carboniferous in eastern Yun-nan. The base of the Lower Permian has been fixed by the same author at the horizon where a unique fauna of brachiopods replaces the Fusulinidae which almost exclusively fill the higher zones of the Upper Carboniferous.

b. MIDDLE PERMIAN. There is no sharp lithological distinction between the Lower Permian and the Middle Permian. The faunas that they contain, however, show a remarkable difference: The Lower Permian fauna chiefly consists of brachiopods; while the Middle Permian fauna is, as in the case of the Upper Carboniferous, characterized by Fusulinidae. The species Doliolina lepida is particularly abundant in the Middle Permian, it sometimes forms a complete bed of limestone. The upper part of the Middle Permian formation generally contains the species Neoschwagerina (Sumatrina) multiseptata n. sp. DEPRAT and Neoschwagerina (Sumatrina) annae Volz.

c. UPPER PERMIAN. The Upper Permian conglomerate rests on rocks of various age indicating marked unconformity between the base of the Upper Permian and those underlying it. Deprat describes many instances showing the unconformable junction. The following is the most typical. At the cutting to the north of Wou-lou-si-shou, the Upper Permian conglomerate overlies the Fusulina multisepta zone. The complete absence of the Upper part of the upper Carboniferous, the Lower and the Middle Permian gives us some idea of the enormous scale of erosion that must have taken place before the deposition of the conglomerate. At a locality about ¼. K.M.S.S.E. of the cutting, the conglomerate rests on the Neoschwagerina craticulifera zone; while in the district of Lan-nin-tsin it discordantly overlies the beds of Doliolina lepida.

The massive conglomerate is followed upwards by a series of sandy deposits of a very inconstant character including marly intercalations and occasional gypseous deposits. The thickness of these locustrine or lagoon deposits is extremely variable; ridges and hollows which characterized the landscape of the country during the transitional period from the Middle Permian to the Upper Permian, are indiscriminately buried underneath it. A splendid example illustrating this effect has been found by Deprat at a locality to the east of Ta-hi-ti, where an underground ridge of the upper carboniferous and the Lower Permian limestone protrudes through the mantle of the Upper Permian deposits like a Chaldean town rising out of the sand. At certain localities in the districts of Pa-mao-tsn, Tchao-Koua, Lou-leang, the effect of the erosion at the end of the Middle Permian time is so clearly shown that the Upper Permian sandy deposits rest upon a veritable peneplain at which the pre-Upper-Permian folds are truncated.

The uppermost volcanic series of the Upper Permian age is well developed in the districts ~~lying~~ between the Tie-tchen-ho and the great fault of Pong-pou and Tchou-yuen. To the east of Wang-tang the whole series attains a thickness of more than 180 m consisting of bedded lava, tuffs and "cinerite". To the west of the lake Tsin-shouei-tang, Deprat observed the following:-

Lower Trias	t_1	Sands and marls.	
(Unconformity)			
Upper Permian	B	Basalt, tuff and "cinerite"	250 m.
	r,,	Conglomerate.	150 m.
		Bands of grits.	20 m.
(Unconformity)			
Upper Carboniferous	H 9-9a	Limestone.	

In the district of Fong-Wou-shan, West of Siun-tien-tcheou and north of the latitude of Yun-nan-fu, the complete sequence of the Permian formations is exposed. According to Deprat, this exposure is probably the continuation of that of the Yo-tiang-shan. He gives the following sequence:-

Upper Permian	B	"Labradorite".	200 m.
(Unconformity)			
Middle Permian	r,a	Limestone with CP a 18 . .	20 m.
	r,	Limestone with CP a 19, to CP a 24.	10 m.
	r II	Dark gray limestone . . . with CP a 17, CP a 24 to CP a 26, etc.	100 m.
Lower Permian	r I	Light gray limestone. . . . with CP b 20, CP b 23 to CP b 28, CP d 5, CP c 12, CP g 9.	150 m.

N.W. YUN-NAN.

In the district of Young-tshang-fou, between Ta-li-fu and Bhamo, Loczy found a fauna consisting of:-[57]

CP b 29, CP b 30, CP g 10.

At Yun-nan-yi, near Ta-li-fu Leclere collected a fauna from a gray marble, including the following species:-[43,264]

CP c 13, CP g 11, CP d 6.

KWEI-CHOU.

A fauna was found in the shale of Ngan-tchoung-po, The material was examined by Douvil̉le who reports the presence of the following species:-[43]

CP b 18, CP b 36, CP b 37, CP d 7.

HU-NAN.

At Lo-shi-kiao, Shao-yang-hsien, Pao-king-fu, the following species occur:-[29]

CP g 12, CP g 15, CP g 13.

At Yang-chia-yu, An-hwa-hsien, chang-sha-fu, Yobe (?) found:-[30]

CP g 14.

From the coal bearing series of Hwang-i-kang in the lower part of the Liu-ho, Richthofen collected a fauna of molluscs largely consisting of lamellibranchs. The following are among the identified species:-[267]

CP f 4 to CP f 16, CP c 14.

Stratigraphical details of the formation yielding this fauna are not known.

WESTERN CHINA.

Between Batang and Ta-tsien-lu, west of the Red Basin of Su-chuan, Loczy found a marine formation which he assigns to the Lower Carboniferous on account of the discovery of Posidonomya becheri.[58]

At Tze-de, near Batang, Loczy collected the following brachiopods:-[59]

CP b 4, CP b 31 to CP b 33.

At Yarkalo[60] (Lat. 29°/30' N.long 98° E), in the valley of the Lan-tsan-kiang, Loczy found an interesting fauna which shows world-wide affinity. The following species are among the identified ones:-

CP b 38 to CP b 43, CP d 8, CP d 9.

In crossing the Kiu-tiau-shan, from Tshau-tien to Kwang-yuan-hsien, (on the northern border of the Red Basin of

Su-chuan) Richthofen followed a sequence of strata dipping towards the north. The sequence consists of the following series:-[92]

7. Overturned strata of indeterminable nature with Atrypa reticuloris. (Thrust plane?)

α 6. Thin-bedded limestone with marly and shaly intercalations.

β 5. Massive limestone containing black and white quartzite. The limestone shows coral-structure.

γ 4. Fine-grained gray limestone with siliceous shale (Kieselschiefer) containing fragments of Productus. In the limestone Spirifer lineatus occurs.

δ 3. Coal bearing series Yellow and gray calcareous shale (Schieferton) crowded with fossils, capped by a seam of bituminous coal 4 feet thick.

ε 2. Flaggy limestone with intercalated thin layers of highly bituminous argillaceous limestone which contains brown ironstones. These parting layers are full of marine fossils; Productus, Aviculopecten, etc. are especially abundant.

ζ 1. Gray limestone with quartzite containing abundant corals and Brachiopods; amongst the latter Spirifer lineatus occurs.

Central and S.E.China.

The Gorge district of the middle Yang-tze.

From San-tou-ping to the Mi-tsan gorge, massive limestones are exposed. Richthofen describes the sequence of the limestones as follows:-[118]

Carboniferous.	13.	Thick-bedded limestone.	
	12.	Blue and White Thin-bedded limestone somewhat crystalline	1500 ft.
	11.	Thin-bedded nodular limestone	1500 ft.
	10.	Thick-bedded limestone free from nodules	150 ft.
	9.	Green shale with dark reddish-brown siliceous limestone. The village of Sin-tan stands on this formation	800 ft.
	8.	Thin-bedded yellow and green limestone striking N 35°E containing fossils CP g 16, CP g 17, CP g 20 CP g 21.	400 ft.
Devonian.	7.	Gray-green sandstone with greenish shaly strata	300 ft.
	6.	(see p 117)	

In the middle Yang-tze region including the districts where Richthofen made his observations described above, Blackwelder distinguishes a mighty limestone formation which he calls the Wu-shan limestone,[181] consisting essentially of dark gray or blackish limestone, (continued next page)

and attaining a thickness of about 4000 ft. The lower part of the Wu-shan limestone contains layers of shales and local seams of anthracite together with flints and insignificant strata of quartzite. This formation is underlain by the Sin-tan series of Siluro-Devonian age (see p 152) and probably overlain by the Kuei-chou series (see p 226); it yields fossils at several horizons: At Tung-kuan-kou from a thin seam of black shale associated with anthracite which is believed to be about 1200 ft above the base of the Wu-shan limestone, Blackwelder obtained the following forms:-

CP b 44 to CP b 46.

In the limestone canon below Ta-ning-hsien, a brownish cherty layer which probably lies in the middle part of the Wu-shan limestone, has yielded the following:-

CP f 18 and Gastropods.

Near the salt well of Yen-chang on the Ta-ning-ho, a dark gray limestone about 800 to 1000 ft above the base of the Wu-shan formation contains the following species:-

CP d 11, CP d 12.

From the basal layer of the Wu-shan formation, 1 mile above the junction of the two main tributaries of the Ta-ning-ho, north of Miau-ir-tan, the following forms have been collected:-

CP b 47 to CP b 51.

2 miles north of Ta-ning-hsien, the base of the Wu-shan limestone which consists of a dark gray limestone with nodules of flints, contains the following:-

CP a 29, CP g 4, CP g 22, CP a 11, CP a 13, CP b 52, CP b 53, CP c 15, CP h 1.

(Note The Wu-shan limestone of Blackwelder is probably identical to the limestone sequence 8 to 13 as described by Richthofen p 181)

S.E.Hupeh

Yabe and Sakahaya state that they have obtained a Permian fauna from Hei-tze-kou, 20 lis south of Wu-chang. The fauna consists of CP g 23, CP b 54 to CP b 57.

At Lung-chiang-chen, Wu-chang-fu, from the Fu-shan coal mine, the following Carboniferous forms have been obtained:- [31]

CP g 24, CP a 30.

Near Hwang-shi-kang, on the northern side of the Yangtze, a hill called Sang-hu-shan (lat. 30° 15'N. long. 115° 10'E) rises to an altitude of about 500 ft above the alluvial plain. The hill assumes a S.E.trend. Crossing this hill, Richthofen has made out the following sequence:- [119]

(see section No. 39)

10. White, brown and brown-red rock (chiefly composed of sandstone?) of considerable thickness.

(Permian.)

(9. Coal bearing series with plant remains. There are no shaly layers in this series.

(8. Soft shaly and sandy rock - - -probably 500 ft.

(7. Tuff-like sandstone with occasional coal seams, without the slightest

(trace of coaly shale.
(
(6. Porphyritic tuff very thick.
(
(5. Porphyry rich in quartz and large
(crystals of orthoclase, highly
(weathered; it forms the dip slope
(of the Sang-hu-shan.
(Permian.) (
(4. White-gray quartz sandstone with
(intercalated siliceous conglomerate
(In the sandstone impressions of
(plant remains occur. They are believed
(to be calamites.

3. Coal-shale with a coal seam 2 ft
thick. Plant remains sparcely occur
in the shale; Schenk identified CP z 2.

(2. Sandstone only partially exposed.
(
(Carboniferous.) (1. Thin-bedded, soft, shaly rock of
(red colour.

To the southwest of the Sang-hu-shan, forming the southern bank of the Yang-tze, there are limestone hills which are composed of highly folded strata; the axes of the folds generally strike from E - W to E 20° N. In the neighbourhood of Shi-hwei-yan, Richthofen followed a sequence from the south to the north. He describes it as follows:-[120]

7. Well stratified limestone free from
hornstone as distinguished from the
underlying series. The individual layers
are sometimes thick-bedded and some-
times in thin laminae. The rock is
hard and splintery and shows a light-
gray colour. Fossils are probably absent.

(6. Light-gray limestone with much horn-
(stone, well-bedded, each bed has a
(thickness from 2 ft to 3 ft.
(
(Permian.) (5. Very soft micaceous sandy coaly-shale
(with a coal seam and sandstone layers
(which contain plant remains. From the
(shale a single species of lammellibranch
(CP f 19 has been found.

-

Permian.

(4. Thin-bedded siliceous shale
(with yellow parting layers.
(
(3. Thick-bedded dark gray lime-
(stone containing much horn-
(stone.
(
(2. Thin-bedded light gray and
(splintery limestone with
yellow shaly layers. The
limestone atrata show wavy
plication.

1. Limestone traversed by a
network of calcite-veins.

The thickness from 2 to 6 is about 800 ft, from 1 to 7 is about 1600 ft.

In the hills near Wei-yuen-ko, about 9 K.M. below Ki-tshon-hsien, Richthofen observed a series of limestone which is lithologically similar to the beds 2 to 6 described above.[2] In this limestone he found a rich Foraminiferal fauna including the following species:-

CP a 25, CP a 28, CP a 4, CP a 30, to CP a 35.

Kiang-si.

To the south of the Mong-shan, near Lo-ping-hsien (lat. 29°N. long. 117° 10'E.), in the basin of the coal measures, Richthofen observed the following sequence and collected an important fauna:

7. Red and yellow sandstone - - - - about 50 ft.

6. Soft argillaceous limestone with a band of hard limestone which yields marine fossils - - - - - - - - - -10 ft.

5. Dark gray sandy shale (Shieferton), perfectly and thinly stratified with indeterminable plant remains and a seam of bad coal - - - - - - - 240 ft.

4. Light gray firm argillaceous limestone rich in marine organic remains.

3. Black marly shale with marine fossils.

2. Dark sandy shale.

(4–2 together) 100 ft.

1. The main coal seam - - - - - - - - - - 10 ft.

The fossils mentioned below are derived from 6, 4 and 3 of the above sequence;

CP h 2, CP e 3 to CP e 6, CP f 20, CP f 21, CP b 39, CP b 21, CP b 40, CP b 31, CP b 58 to CP b 78, CP d 15, CP g 25, CP a 36, CP d 16.

The lower Yang-tze valley.

On the northern slope of the Pu-ki-shan, near Kiu-li-tswan, Ning-kwo-hsien, (lat. 30° 25'N. long. 118° 53'E.) Richthofen observed the following sequence of rocks:-[122]

5. A series of yellow sandstone.

4. Coal bearing shale containing Ammonites. The coal is worked.

3. Massive Fusulina limestone.

2. Sandstone series.

1. Massive limestone containing coal bearing shales.

To the east of Nan-king, on the southern bank of the Yang-tze, a steep hill rises to an altitude of about 1200 ft above the river level. (about lat. 32° 15'N. long. 119° 10'E.) On the top of this hill, a single old tree stands aloft. Hence the hill is popularly known as the "Single-tree-hill". The proper name of this hill is Hsi-hsia-shan. Richthofen describes the Hsi-hsia-shan as a compressed syncline formed by a sequence of the following rocks:-[123] (see section No.46)

8. Loess.

7. White quartz sandstone cemented by white spongy material and interstratified with conglomerate which contains well-rounded quartz pebbles. The sandstone contains reed-like plant remains - - - - - - - - - - - - 1500 ft.

6. Thin-bedded marly sandstone and sandy marl of red and yellow colour - - - about 100 ft.

(Lower Carboniferous.)

5. Alternating beds of fossiliferous dark gray limestone and marly shale which becomes sandy towards the upper part of the series. The black shale is sometimes coaly and contains traces of plant remains.

4. Dark gray, hard, splintery, thick-bedded limestone with lenticles of "firestone" and inclusions of siliceous

Lower Carboniferous. sponge. The strata are bituminous; yellowish in colour and semicrystalline in texture. Fossils occur in abundance in the upper part of the series. The following are among the identified species - - - - - - - - - 250 ft.

CP g 18, CP g 12, CP g 21, CP g 26,

CP g 27, CP d 10.

3. Black and brown sandstone and conglomerate containing pebbles of quartz.

2. Interbedded soft quartz sandstone and soft, mottled shale.

1. Variegated soft shale with the admixture of manganiferous shaly-ironstone.

To the south of Pa-hwei-miau (lat. 32° 10'N. long. 119° 15'E.) and north of Tang-shui, Richthofen observed a synclinal hill consisting of the following strata;,

Carboniferous.

6. Coal bearing series of Pa-hwei-miau. This series is not involved in the syncline.

5. Hard thick-bedded quartzite.

4. Gray limestone containing lenticles of black "firestone" and laminated siliceous intercalations with weathered and silicified fossils. (Richthofen remarks that this series is indisputably identical with the Lower Carboniferous limestone of the Hsi-hsia-shan)

Devonian.

3. Quartzite and quartz sandstone striking E - W and dipping 60 N.

2. Dark gray-green crumbly shale.

1. Quartzite which probably forms the bulk of the hill.

Immediately to the east of the city of Nan-king, the hill of Tshung-shan forms a conspicous escarpment on its northwestern flank. The city wall runs along the lower part of this scarp. In this hill Richthofen found a series of coarse-grained sandstone and conglomerate dipping persistently towards the S.E. These are overlain by yellowish cellular sandstone and black shale. The shale is full of fucoidal-like plant remains. Overlying the shaly strata are again sandstone and conglomerate containing large pebbles of quartz. Further S.E. after a long interuption of observation, Richthofen found, in a deep ditch, the exposure of red sandstone and coarse red conglomerate with well-rounded pebbles of quartz, porphyry and limestone which is finally buried by the loess.[124] (Compare Kingsmill's observation p 157)

Similar sandstone and conglomerate are exposed in the hills lying between Pa-hwei-miau and Tung-yang, west of the Tshung-shan. To the east of the Tshung-shan, red sandstone and conglomerate also occur, overlying a yellow limestone; the former continue to run towards east and are once more exposed at the Hsi-hsia-shan where they are underlain by the Lower Carboniferous limestone. Richthofen, therefore, assigns these sandstone and conglomerate to the Upper Carboniferous.

In the lateral valley separating the Tshu-shan from the Kau-li-shan, west of Cheng-kiang, Richthofen noted the following sequence:-[115] (see section 45)

5. Limestone which is in the neighbourhood of the valley directly overlain by coal, the latter in turn ~~is~~ being buried under the loess.

(4. Coal bearing series of sandy and shaly strata forming the undulatory hilly country lying on the south of the Tshu-shan - - - about 400 ft.

(This series admits further subdivision (as follows.

(f. Dark sand and carbonaceous shale with a seam of coal.

(e. Brown sandstone with plant remains.

(Interruption of observation)

(c. Black siliceous shale unfossiliferous.

(Permain.) (Interruption of observation)

(a. Very impure fine-grained sandstone with intercalated limestone. Firestone occurs in the lower part of the series. Productus and other brachiopods, Fenestella, corals, etc. have been found.

(3. Well-bedded limestone containing firestone. The upper part of the limestone is a red variety of splintery nature, in which are found crinoidal stems and abundant Fusulina together with CP b 91, CP b 92, CP g 28. This series is divisible into two sub-series:-

b. Mainly limestone - - - - - - - - - 400 ft.

a. Shaly strata with big ~~lenses~~ lenticles of firestone - - - - - - - - - - - -1000 ft.

2. Quartz sandstone and conglomerate with yellow, brown, and white quartz pebbles. (Richthofen remarks that this formation is almost identical with the coarse sandstone and conglomerate of the Hsi-hia-shan. Its thickness is very variable: On the west of the valley it forms high peaks, attaining a thickness of ~~at~~ 800 ft. while to the

east of a narrow in the valley, it is much thinner.)

1. Granite with large porphyritic felspars. It weathers to a blackish colour. (Intrusion).

The whole of the above sequence strikes E N E and dips 30° S S E. Towards the East the strike changes into E - W. About 4 K.M. east of Lung-tan, on the flank of the Lun-shan, the quartzite (2) is found to rest on a graptolitic slate. (see p 128).

Che-kiang.

At Kiai-kou (lat. 29° 45'N. long. 118° 45'E.), on the divide between the province of Che-kiang and Kiang-si, Richthofen observed a large anticline in which he was able to make out the following sequence:-[125]

5. Quartz Porphyry traversing a sandstone.

4. Quartzitic sandstone.

3. Quartzose and quartzitic slates (Schiefer) partly black and partly yellow, green or white. The lamellae of the slate are separated by scaly and talcy soft layers.) 800 ft. (3 and 2)

2. A series of interbedded calcareous and siliceous rocks. The calcareous rock is generally a crystalline bituminous limestone of grayish colour and fine texture; the siliceous rock consists of the following:-

   c. Thin-bedded quartzite and other siliceous rocks.

   b. White slate. The surface of the individual layers are often marked by long straight lines, probably due to organic remains.

a. Exceedingly fine black siliceous slate

In these strata, coaly substance often occurs. The narrow black siliceous slate is strongly bituminous with thin seams of extremely impure coal which is used in the district for lime-burning.) 800 ft.

(Note These rocks seem to bear certain lithological resemblance to the "Culm measures" of Britain)

1. Limestone.

In the neighbourhood of the lake of Si-hu, outside the city of Hang-chou (lat. 30° 10'N. long. 120° E.), Richthofen followed a sequence of rocks from N.E. to S.W. He describes it as follows:- (see section No.47) 126

4. Red quartz porphyry and its tuffs.

3. Quartzite-like brown sandstone.

2. Limestone.

1. Coarse-grained hard sandstone.

In the lake of Tai-hu, on the northern border of the province of Che-kiang, a limestone island stands between the sandstone hills of Si-tung-ting and Tung-tung-ting. This limestone is charged with yellow-brown earthy material and crystals of calcite. Only 250 ft of it is seen above the water. Richthofen says that the total thickness of the limestone cannot be more than 800 ft. It contains abundant organic remains. In the material collected by

Richthofen, Schwager identified the following foraminifera,

CP a 8, CP a 13, CP a 37.

Besides the Protozoa there occurs many species of crinoids, corals and gastropods. Unfortunately they have not been described.

Tiessen remarks that this fossiliferous limestone and the sandstone exposed in the Tung-tung-ting and the Si-tung-ting are identical with those occurring in the neighbourhood of the Si-hu.

Northern China.

As already stated in the general remarks, the lithological nature of the upper palaeozoic rocks and their general stratigraphical relation with other systems are essentially similar over the whole area of northern China. The only exception to this rule is met in the northwestern corner of the country, viz., the Nan-shan region, where massive marine formations yielding Middle Carboniferous and Upper Carboniferous faunas such as Spirifer mosquensis, Productus semireticulatus, Fusulina cylindrica, Schwagerina princeps, Doliolina verbeeki, Productus caneriniformis, etc, have been found. According to Futterer the "Doliolina formation" alone forms the bulk of the Semenow mountains near the lake Ku-ku-nor.

Elsewhere in Northern China, the Carboniferous-Permian period is at least partially represented by the Shan-

sian

system. The following records of observations will suffice to show the extensive distribution of this system.

Ho-nan

In the Ja-mei-sen colliery, northern Ho-nan, Reid makes out the following sequence of the so-called coal measures: (cf. 4, 28)

	Alluvium	
	Red and yellow clays; Conglomerate	250 ft.
	Arenaceous clays and shales; Yellow and brown sandstone	90 ft.
"Coal measures"	Shales and sandstones	250 ft.
"Coal measures"	Main coal seams	18 ft.
"Coal measures"	Shales and sandstones	250 ft.
"Coal measures"	Flinty limestones	30 ft.
"Coal measures"	Brown and yellow sandstone with bands of iron ore	80 ft.
	"Carboniferous limestone	2000 ft.

This section is believed to be fairly typical over the whole area of northern Ho-nan. The lowest member in the sequence, i.e., the "carboniferous limestone" is not true carboniferous limestone, but is so called by the miners because it underlies the "coal measures". From the information furnished by Richthofen and others, the writer judges it to be the Sinisian limestone which we have already dealt with.

Shan-si.

The Shansian system is excellently developed in the province of Shan-si. It occurs in an extensive sheet forming the upper part of the plateaus, being upthrust by mighty faults. Natural profile showing the succession of the rocks is often seen along the wall-like edges of the plateaus. Different geologists generally agree in describing the sequence of the strata, but their deduction of age is not always the same.

Approaching the Tai-hung-shan, the southeastern edge of the Shan-si plateau, from the plain of Hwai-king-fu, Richthofen travelled across the complete succession of the rocks belonging to the Shansian system between Yu-tai and the small temple of Kwan-wang-miau. He describes it as follows:- (see section No.30)[93]

4. Unstratified sandstone.

Shansian.)
(3. Variegated sandstone containing anthracite seams.
(2. Tai-yang- series. Alternating beds of limestones, shales and sandstones, and in places being capped by a black limestone. Near Hsiau-kou, (40 lis north of Yu-tai) the black limestone contains corals Spirifers, Orthoceras, Crinoids and Fusulina.
((Richthofen compares this variable series with the similar rocks which he found in the Po-shan coal field in Shan-tung.)

(Sinisian.) (1. Very thick limestone, partially
(dolonitized. This is well exposed
(on the edge of the plateau.

The series (4) in the above sequence is sometimes called by Richthofen the "plateau sandstone" or the "plateau-schicten" It attains a considerable thickness.

Between Tai-yuan-fu and Wen-shui-hsien, the exposure of the Shansian rocks are almost continuously exposed. Willis and Blackwelder divides the whole system into two series[182]

Upper. Reddish sandstone with subordinate sandy shale.

Lower. Soft shale of various colours, containing coal seams and resting directly upon the Sinisian limestone.

Immediately north of Yön-yi-ssi half way between Ling-shi-hsien and Ho-chou, from a local bituminous limestone interbedded with shales, Blackwelder collected the following species:-

CP b 79, CP b 80, and Ostracoda indt.

Near the hills of Hou-yu-koo, west of Tai-yuan-fu, Leprince-Ringuet collected the following species from a highly fossiliferous limestone.[50]

CP 81 to CP 84, CP b 63?.

A rich flora has been collected from the Shansian coal measures. The exact localities and horizons which yield the flora are not known. It includes the species CP z 3 to CP z 27.

N.T.Williams describes the general succession of the Shansian coal measures as follows:-[155]

5. Yellow-brown sandstone clay and shale. This series is often denuded away; At Tze-chou where it is partially preserved its thickness reaches 1000 ft.

4. Shales and red sandstone - - - -100 to 300 ft.

3. Coal seam, persistent over a large area - - - - - - - - - - - - - 12 to 30 ft.

2. Sandstones and shales capped by a layer of fire-clay - - - - - - - - 200 to 300 ft

1. Flinty limestone containing abundant brachiopods and resting upon a sandstone - - - - - - - - - - - - - - - 10 to 15 ft.

According to Williams, coal seams sometimes occur below the flinty limestone. It is significant that this section is almost strictly comparable with that given by Reid in northern Ho-nan (see p 194)

Chi-li.

In the Ning-shan district,[183] northwest of Tang-hsien (lat. 38° 40'N. long.115°E.), there are three isolated areas of the Shansian rocks lying in a large syncline: (1) In the Ning-shan coal field, the productive measures consist of variegated shales and sandstone, As a rule, the higher beds are more sandy than the lower ones which contain coal seams. (2) In the Tien-hua and Yau-tou coal fields, the coal measures are so deeply dissected by the Tai-shan-ho that the underlying Sinisian limestone is exposed. (3) At Mi-cheng, the Shansian coal measures are preserved in a sharp trough or basin. The nature of the rocks is essentially the same as in the Ming-shan coal field.

In the Wang-ping coal field,[20] about 20 miles west of Peking, F.N.Drake makes out the succession of the rocks belonging to the Shansian coal measures as follows:-

I. Sandstone - - - - - - - - - - - - - - - thick.

H. Principally sandstone interstratified with thin clay shales and some coal - -400 ft.

G. Shaly sandstone and clay shales - - - 200 ft.

F. Massive green sandstone - - - - - - - - 500 ft.

E. Principally shale with thin-bedded sandstone - - - - - - - - - - - - - - - - - 500 ft.

D. Chert conglomerate and grit - - - - - 25 ft.

D to C. Carboniferous clay shale - - - - 50 ft.

C. Coal - 35 ft.

B. Carboniferous clay shale with a little sandstone - - - - - - - - - - - -- 250 ft.

A. Limestone - - - - - - - - - - - - - - - - - 2000 ft.

Drake remarks that the conglomerate bed D and the limestone A are the best guide for locating the coal seam C in the underground workings. The limestone A is undoubtedly the Sinisian limestone.

Shan-tung.

In the Shan-tung the Shansian coal measures occur on the downthrow side of large normal faults. They generally rests unconformably upon the Sinisian limestone, and passes upward into a massive red sandstone with interbedded lava which is believed by Richthofen to be of Permain age.

In the vicinity of Yen-chuang, Near Sin-tai-hsien, the productive measures occupy a large part of the plain east of the Wen-ho. The upper part of the series consists of quartzose sandstone and yellow shale with interbedded lava and tuff. The lower part of the series is generally composed of yellow, gray, black shales with subordinate amount of sandstone. Several coal seams occur near the base of the series. Associating with the coal seams there is a layer of black bituminous limestone which yields marine fossils, such as CP b 44, CP b 46, CP 86, CP 85. According to Blackwelder the total thickness of the Shansian coal measure in this district may exceed 2000 ft.[184]

In the Po-shan and the Hei-shan coal fields, Richthofen collected a marine fauna out of which Frech has determined the following species:-[267, 268]

CP b 83, CP b 87, CP b 88, CP b 38, CP b 39, CP b 56, CP b 61, CP b 90, CP c 16, CP c 17, CP c 18.

According to Richthofen, there are several marine bands which either form the lower part of the productive measures or immediately underlie~~s~~ them. He does not state ~~that from what~~ the horizon or horizons from which the fauna was obtained.

Elsewhere in Shan-tung, the nature of the Shansian rocks is essentially the same as in the Po-shan coal field.

(III) Correlation.

In eastern Yun-nan, the different stages of the carboniferous and the Permain formations have been carefully compared by Deprat with the equivalent developement in the other parts of the world. Further discussion on the age of the rocks seems to be unnecessary. Elsewhere in China, the classification of the upper palaeozoic rocks has not been definitely established. From all that we know, four stages seem to be distinguishable (a) Lower Carboniferous (b) Upper Carboniferous (c) Lower Permian (d) Upper Permian Granting this tentative classification, we now proceed to seek for the representatives of each stage.

(a) Lower Carboniferous.

<u>In northwestern Yun-nan,</u> the Young-tchang-fou fauna (p 178) is regarded by Deprat as comparable with the lower carboniferous of eastern Yun-nan.

<u>In Central Hu-nan,</u> the presence of the Lower Carboniferous formation is indicated by the Lo-shi-kiao fauna, (p 179)

In northern Su-chuan, the thick marine formation with Brachiopods and a coal seam (p 180) suggests its carboniferous age; but definite correlation is impossible without further data.

<u>In the gorge district of the Yang-tze,</u> the massive Wu-shan limestone yields fossils at several horizons. (p 182) The fossils are described by Girty who concludes that the collective fauna is related to that of the Salt range of India and the Gschelstufe of Russia; following this view, Blackwelder assigns the whole of the Wu-shan limestone (about 4000 ft thick) to the Upper Carboniferous. At the base of the same limestone, Richthofen collected a fauna (p 181) which according to Frech,[269] indicates Lower

Carboniferous age. Thus there is a conflict of opinion.

Considering both from palaeontological and stratigraphical point of view, the writer finds himself in favour of Frech's opinion, i.e., to regard the base of the Wu-shan limestone as Lower Carboniferous. None of the forms mentioned by Girty is typically Upper Carboniferous, on the other hand the species Michelinia favosa and other corals are well-known Lower Carboniferous forms in Europe. Moreover only a few feet of shale intervene between the base of the Wu-shan limestone and the next fossiliferous horizon below it; the latter is either of Lower Carboniferous age or older. (see p 159) Therefore in the absence of an unconformity at the base of the Wu-shan formation, it is difficult to regard the lower part of the Wu-shan limestone as appreciably younger than the Lower Carboniferous.

<u>In the Hsi-hsia-shan,</u> the dark gray limestone (4) (p 187) contains a fauna which undoubtedly belongs to the Lower Carboniferous as pointed out by Frech. This limestone formation is of great stratigraphical importance, for the correlation of the Palaeozoic ~~strata~~ rocks in the Lower Yang-tze valley is largely based on their relative stratigraphical position with respect to this fossiliferous formation.

The exposure of a marine formation in the <u>Kiai-kou district</u> (p 191) shows the presence of a peculiar group of rocks which may represent a facies of the carboniferous ~~formation~~ in S.E.China.

The hornstone bearing limestones of the Ta-hua-shan, the Tung-kwan-shan, and the Hsiau-hua-shan, southern An-hwei, (p 155) with sponges, corals, brachiopods and crinoids, are believed by Richthofen to ~~be~~ belong~~ing~~ to the Lower Carboniferous. Although these limestones are petrographically dissimilar to that of the Hsi-hsia-shan limestone, Richthofen thinks that the dissimilarity is to be regarded as representing varieties of the Lower Carboniferous limestone in the lower Yang-tze valley, rather than characterizing different groups of rocks. Moreover, the said limestones are overlain and underlain by coarse deposits both in the case of Hsi-hsia-shan and the other districts in An-hwei.

(b) Upper Carboniferous.

In the Hsi-hsia-shan section, the sandstone and conglomerate (7) (see p 187) is regarded by Tiessen as Upper Carboniferous on account of the fact that similar rocks are overlain by the Fusulina limestone ~~in~~ of the Tshu-shan 127 (p 190) The latter is correlated by Frech with the Productus limestone of the Salt Range.

The conglomerate of the Tshung-shan and the adjoining hill ranges (p.189) near Nan-king is according to Richthofen the same formation as the conglomerate ~~as~~ exposed in the Hsi-hsia-shan. Since we have assigned the conglomerate of the Hsi-hsia-shan to the Upper Carboniferous, we may also regard the Tshung-shan conglomerate as Upper Carboniferous.

The Fusulina bearing limestone of the Tai-hu and the

Hang-tshou districts (p 192) are identical as pointed out by Tiessen. They contain no firestones, and are disting-uished from the Fusulina limestone occurring in the Nan-king district by the fact that they are distinctly bituminous, that they contain thick parting beds; and that they include layers of indented plates. (einander verzahnte Schicht-flöcken) And since their thickness is considerably less than the Fusulina limestone of the Nan-king district, Richthofen thinks that the Fusulina bearing limestone of the Hang-tshou district is not identical with the Fusulina lime-stone of the Nan-king district, but admits that they are most probably equivalent in part. Having scarcely any reason to suppose that the Fusulina bearing limestone of Hang-tshou represents the upper stage of the Fusulina limestone of Nan-king, he considers the former as equivalent to the lower part of the latter.[128] Comparing the fauna contained by the Fusulina bearing limestone of Hang-tshou with that of Upper Carbonif-erous of eastern Yun-nan, the writer is confident that he may place them in an equivalent position because of the presence of Fusulina brevicula and Schwagerina princeps in both of the faunas.

The Lo-ping fauna (p 186) has given rise to different opinions as regards the age of its containing rock. The fauna has been described by Kayser[275] who regards it as Upper Carboniferous; Frech, however, places it in the Permian[267] (Obere Palaodyas); Loczy correlates it with the Moscovian or

Middle Carboniferous; G. Filiegel[266] concludes that it represents younger Upper Carboniferous. Deprat correlates it with the Uralian or the Upper Carboniferous of eastern Yun-nan. It should be noted that among the 55 species described by Kayser a number of Brachiopods, Bryozoa, and corals also occur in the Upper Carboniferous of eastern Yun-nan. The Upper Carbon iferous fauna in Yun-nan is decidedly foraminiferal, while the Lo-ping fauna is predominantly molluscan. Fliegel considers the Lo-ping fauna as slightly older than that of Padang, Sumatra.[305] This correlation would place the Lo-ping coal bearing series in a somewhat equivalent position to the Lower Productus limestone of India. The presence of Strophalosia, Richthofenia, Lyttonia, (=Leptodus KAYS.) etc., is in favour of this view. Further, the fauna has certain affinity to the Artinskian; therefore it cannot be much older than the Lower Permian. Thus the writer is led to agree with Fliegel in regarding the Lo-ping coal bearing series as the uppermost stage of the Upper Carboniferous.

The Yarkale fauna (p 179) probably was not obtained frm from a single series for it indicates different ages. The species Spirifer planoconvexus and Septopora biserialis occur in the permo-carboniferous of Nebraska and Illinois; Camarophoria ranges from Uralian to Artinskian in the Ural region; but the polypora appears in the Lower Carboniferous of Belgium. Some of the other species are present in the Middle Productus limestone of the Salt Range. The presence of this fauna on the eastern Tibetan border proves it conclusively that the present upland in western China was under the world-wide Carboniferous and Permo-Carboniferous sea.

Finally we have the great Shansian productive measures to deal with (pp 194 – 199) Since Frech announced the opinion that the fauna derived from the Po-shan and Hei-shan coal fields (p 199) Shan-tung, indicates Lower Carboniferous age,[268] it has been generally believed that the ~~Carboniferous~~ Palaeozoic coal bearing rocks in that province are of Lower Carboniferous age. After studying the fauna collected by Willis and Blackwelder (p 199), Girty concludes that it is comparable with that of the Pennsylvanian of North America; and hence he assigns the ~~Shansian~~ Palaeozoic productive measures of Shan-tung ~~northern China~~ to the Upper Carboniferous.[273] Recently a paper[274] dealing with the Brachiopods found in the Carboniferous rocks in Shan-tung has been published by Sakahaya who made a determined attack on Frech's opinion ~~in wholesale~~; he even doubts the authority of Frech's specific determination, stating that the figures and photographs given by Frech show that the material collected by Richthofen is too fragmentary to permit an accurate determination. Sakahaya says that he has obtained two species from a black limestone 1 to 3 m thick namely Productus cf semireticulatus var. hermosanus GIRTY and Productus (marginifera) typicus var. septentrionalis TSCHERN. The latter occurs in the uppermost bed of the Carboniferous in Russia. This fact together with the occurrence of Fusulina[306] lead Sakahaya to ~~advance~~ express the opinion that the black limestone probably represents the highest horizon of the carboniferous formation in

Shan-tung. This black limestone appears to be the same limestone layer from which Willis and Blackwelder made their collection of fossils. It is uncertain as to whether the fauna described by Frech is derived from the same horizon; judging from the fact that carboniferous limestones do not attain great development in Shan-tung, and that they are generally found near the base of the coal bearing series, the fossiliferous horizons cannot be separated by considerable thickness of rocks even if there are several horizons which yield marine organisms. In attempting to remove this apparent palaeontological conflict, Yabe[297] suggests that there may be an unconformity between the Lower and the Upper Carboniferous in Shan-tung; but his suggestion is not borne out by facts.

The fauna collected by Leprince-Ringuet in Shan-si (p 196) was studied by Douville who failed to arrive at any definite conclusion as regards the age of the containing rock But he suggests that it appears to represent Westphalian or possibly a somewhat earlier stage.

The evidence furnished by the flora (p 196) derived from the Shansian productive measures is still more surprising. Zeiller[301] says that the species Taeniopteris multinervis is only known in the Permain in Europe, and it never occurs in the Stephanian. (The other forms generally indicate the upper stage of the Stephanian or the Lower stage of the Autunian.)

Taking the mean of the different cases mentioned above, & regarding the palaeozoic coal bearing rocks in N. China as essentially contemporaneous, the writer tentatively ~~regards~~ assigns the Shansian productive measures to a period ranging from the uppermost carboniferous to the lowest Permian, viz., the permo-carboniferous period.

(c) Lower Permian.

In the previous paragraph, we have already determined the age of the Shansian productive measures in northern China to be permo-carboniferous. Following this determination, a part of the upper Shansian system i.e., the barren sandstones and shales (pp 196-199) may be tentatively referred to the Lower Permian.

In the Tchu-shan section, (p 190) Richthofen mentions a mighty series of Fusulina limestone (3) overlying quartz sandstone and conglomerate; the latter overlies the Lower Carboniferous limestone of the Hsi-hia-shan. On account of the presence of Productus limatus and Lonsdaleia waageni, Waagen compares the Fusulina limestone (3) with the Zechstein, while Frech correlates it with the productus limestone of the Salt Range chiefly because of the presence of Productus indicus.[267] Richthofen thinks that the lower part of the Fusulina limestone is equivalent to the Fusulina bearing limestone of Hang-tshou which we have already palaeontologically determined to be of Upper Carboniferous age. If Richthofen's suggestion is a correct one, the upper part of the Fusulina limestone (3) would necessarily belong to the Lower Permian in the absence of an unconformity between the upper part and the lower part of the same limestone. This agrees with Frech's correlation, Waagen's comparison with the Zechstein rather suggests the Upper or Middle Permian age of the limestone. Since Richthofen does not state the definite horizons from which the fossils were obtained, we are unable to determine what portion of the Fusulina limestone (3) belongs to the Lower Permian.

The coal bearing series (4) of the Pu-ki-shan (p 186) yields a cephalopod fauna which, according to Frech, is comparable with the Artinskian of Russia. It seems to the writer that the general succession of the rocks in the Pu-ki-shan is comparable with that of the Tshu-shan except the uppermost series. If this comparison does hold, the coal bearing series (4) of the Pu-ki-shan would be probably equivalent to the coal bearing series (4) of the Tshu-shan. In the previous paragraph, we have determined that the Fusulina limestone ~~to be~~ either entirely or partially belong to the Lower Permain ~~or partially belonging to the Lower Permian.~~ If Frech's correlation of the coal bearing series with the Artinskian is correct, and if the comparison suggested here by the writer holds, the whole of the coal bearing series (4) and the upper part of the Fusulina limestone (5) both in the Pu-ki-shan and the Tshu-shan would be the Lower Permian representatives.

The Foraminiferal limestone of Shi-hwei-yau and Ki-tshon-hsien (pp 184-185) yield Schwagerina verbecki, Texastria conica, Schwagerina craticulifera, which are also found in the Middle Permian of eastern Yun-nan. Here again we meet the difficulty of finding the exact horizons from which these fossils were collected. However it seems justifiable to assume that these Protozoa are derived from the limestone series below the series (4) in the Shi-hwei-yan section, accordingly we may regard the limestone below ~~some~~ horizon in the limestone(3) as the Lower Permain.

In the Hwang-shi-kang section (p 183), the fossil plant ~~remain~~ obtained by Richthofen from the coal bearing series (3) is, according to Schenk, related to Rhabdocarpus ovoideus which occurs in the Rothliegende. Hence Schenk believes that the series (3) is of Lower Permain age.

The Yun-nan-yi fauna. (p 178) occurs in association with small polypiers. (Favositidae and multiporidae) Douville compares this fauna with that of the Productus limestone of Indo-China and the Permian of Russia, principally because of the presence of Stenopora. The fauna of Ngan-tshoung-po (p 178) is likewise compared by Douville with that of the Productus limestone of Indo-China.

(d) Upper Permain.

The plant remains (such as Cordaites, Stigmaria, Calamites) that have been obtained from the upper part of the Shansian system in Shan-tung which contains lava flows indicate that their containing rock cannot be much younger than the youngest palaeozoic; and we have already determined that the lower part of the Shansian system ranges from the Permo-Carboniferous to the Lower Permian. Hence the writer is inclined to place the uppermost part of the Shansian system in the Upper Permian, but does not preclude the possibility that it may range upwards into the Permo-Trias and downwards into the Lower Permain. This correlation is corroberated by the fact that volcanic eruption was also fully active in eastern Yun-nan in the Upper Permian time.

<u>The upper most part of the Shansian system in the provinces of Shan-si and Chi-li</u> may represent the upper Permain; but the writer is unable to produce any evidence and he regards this correlation as a mere suggestion.

<u>In the Hwang-shi-kang section</u> (p 163) we have bedded porphyry, phorphyritic tuff and sandstones attaining a thickness of 4000 ft, being underlain by ~~and overlying~~ sandstone and coal bearing rocks which we have regarded as Lower Permian. From the determination of age it follows ~~latter fact we determine~~ that these volcanic rocks and their interbedded sandstones and shales cannot be older than the Lower Permian; and they do not seem to be Mesozoic deposits for volcanic activity is not recorded in the Mesozoic rocks elsewhere in the middle Yang-tze valley; certainly they cannot be younger than the Mesozoic. Therefore we may regard the volcanic series and the interbedded deposits as Upper Permain. As in the ~~previous~~ case of Shan-tung, for this correlation we have the support from eastern Yun-nan where vulcanicity in the Upper Permian time is known.

The writer is unable to assign a definite age to the coal bearing series (4) of the Tshu-shan (p 190) and the Pu-ki-shan (p 187), but suggests that they may belong to the Middle or Upper Permian.

<u>The Hwang-i-kang fauna</u> (p 179) is described by Frech who states

that the fauna, at the first sight, gives him an impression of being Trias because of the occurrence of Pecten Alberti, but the presence of Aviculopecten coxanus var. sinensis, Schizodus and Bellerophon puts him back to the Palaeozoic. After carefully weighing the chronological value carried by this unique fauna, Frech decides to announce that the productive measures of Hwang-i-kang is of the uppermost Permian age. (Obere Neo-Dyas) Seeing that the succession of the major groups of rocks is practically alike in most of the coal fields in the provinces of Hu-nan and Kwang-tung, as may be inferred from Richthofen's field notes, Frech is inclined to assign the uppermost Permian age to all the anthracite bearing rocks in these two provinces. The writer however thinks that this bold declaration is too premature.

The lower part of the Kuei-chou series (p 226) has yielded a fauna consisting of Dielasma sp. (cf D.elongatum) Aviculopecten (?) richthofeni GIRTY, crinoid fragments and Foraminiferal tests (resembling those of the family Textulariidae). According to Girty, this fauna indicates the youngest Palaeozoic rather than the oldest Mesozoic.

L I S T No 3.

FOSSILS FOUND IN CARBONIFEROUS-PERMIAN ROCKS IN CHINA.

Note The reference no. of each species is only used in this thesis for convenience.

Reference No.	Names	Stratigraphical position						Originally described in — (See bibliography)	Mentioned in this thesis in p. —
		Lower Carboniferous	Middle Carboniferous	Upper Carboniferous	Lower Permian	Middle Permian	Upper Permian		
	(a) PROTOZOA								
CPaI	Spirillina plana MOLL.		x						
CPa2	Spirillina irregularis MOLL.		x	x					
CPa3	Spirillina subangulata MOLL.		x						
CPa4	Tetrataxis conica EHRENB.		x			x			
CPa5	Fusulina regularis SCHELLW.			x					
CPa6	Fusulina kattaensis SCHW.			x					
CPa7	Fusulina tcheng-kiangensis n. sp.			x					
CPa8	Fusulina brevicula			x					
CPa9	Fusulina multisepta SCHELLW.			x					
CPaIO	Fusulina incisa SCHELLW.			x					
CPaII	Doliclina claudiae n. sp. DEPRAT.			x					
CPaI2	Doliclina aliciae n. sp. DEPRAT.			x					
CPaI3	Schwagerina princeps EHRENB.			x					
CPaI4	Neoschwagerina craticulifera SCHWAG. . . .			x					
CPaI5	Neoschwagerina multicircumvoluta n. sp. DEPRAT.			x					
CPaI6	Fusulina alpina SCHELLW.			x					
CPaI7	Doliolina lepida					x			

CPaI8	Neoschwagerina (Sumatrina) multiseptata n. sp.					x			
CPaI9	Neoschwagerina (Sumatrina) annae VOLZ. . .					x			
CPa20	Neoschwagerina globsa YABE.					x			
CPa2I	Doliolina pseudolepida n. sp. DEPRAT. . .					x			
CPa22	Schwagerina douvillei n. sp. DEPRAT. . . .					x			
CPa23	Fusulina marghertii n. sp. DEPRAT.					x			
CPa24	Fusulina exilis SCHWAG.					x			
CPa25	Schwagerina verbecki GEIN.					x			
CPa26	Fusulina richthofeni SCHWAG.					x			
CPa27	Fusulina japonica					x			
CPa28	Schwagerina craticulifera					x			
CPa29	Schwagerina sp.			?					
CPa30	Fusulinella		?	?		?			
CPa3I	Schwagerina lepida n. sp. SCHWAG.					?			
CPa32	Climacammina protenta n. sp. SCHWAG. . . .					?			
CPa33	Valvulina cf. bulloides BRADY.					?			
CPa34	Climacammina cribigera n. sp. SCHWAG. . .					?			
CPa35	Lingulina sp.					?			
CPa36	Fusulina cylindrica FISCHER ?			x					
CPa37	Schwagerina glomerosa (?) SCHWAG								

(b) BRACHIOPODA

CPbI	Martinia glabra	X							
CPb2	Productus cora	X							

CPb3	Chonetes papilionacea PHILL.	x							
CPb4	Productus cf. gratiosus WAAG.								
CPb5	Productella spinulosa	x							
CPb6	Productus striata	x							
CPb7	Productus undatus DEER.	x							
CPb8	Spirifer subconicus MART.	x							
CPb9	Spirifer insculpta PHILL.	x							
CPbI0	Rhynchonella angulata LIN.NE	x							
CPbII	Productus cf. striatus FSCH. DEW.	x							
CPbI2	Productus nystianus DE KON. var. lopingensis.	x							
CPbI3	Orthothetes crenistria PHILL. var. cylindrica M'COY.	x							
CPbI4	Athyris subtilita HALL.	x		x					
CPbI5	Spirifer mosquensis		x						
CPbI6	Productus cf. subcostatus		x	x					
CPbI7	Athyris cf. subtilita MOLL.		x						
CPbI8	Spiriferina cristata SCHLOTH.		x	x	?				
CPbI9	Orthothetes crenistria PHILL. var. senilis PHILL.		x						
CPb20	Spirifer blassi.				x				
CPb2I	Reticularia lineata MART.			x					
CPb22	Productus cf. compressus WAAG.			x					
CPb23	Spirigerella grandis WAAG.				x				
CPb24	Camarophoria globulina PHILL.				x				
CPb25	Hemiptychina sparsiplicata WAAG.				x				
CPb26	Martiniopsis inflata WAAG.				x				

CPb27	Athyris cf. angulata MANSUY.				x				
CPb28	Productus gratiosus WAAG.				x				
CPb29	Productus yunnanensis LOCZY.	x							
CPb30	Productus punctatus LOCZY.	x							
CPb3I	Spirigera (Athyris) globularis PHILL.								
CPb32	Productus cf. ovalis WAAG.								
CPb33	Productus aff. semireticulatus MART.								
CPb34	Uncinella indica.			?		x			
CPb35	Athyris cf. media			?	?				
CPb36	Productus intermedia			?	?				
CPb37	Chonetalla			?	?				
CPb38	Productus scabriculus MART.	?	?	?					
CPb39	Productus semireticulatus MART.	x		x					
CPb40	Reticularia waageni LOCZY								
CPb4I	Uncinulus timorensis BEYR								
CPb42	Spirifer (Martinia) planoconvexus SCHUM. .			x					
CPb43	Camarophoria purdoni DAV.			x	x				
CPb44	Chonetes sp.			?					
CPb45	Ambocoelia sp. (cf. A. Planiconvexa)			?					
CPb46	Cleiothyris (?) sp.			?					
CPb47	Carnegia bassleri GIRTY.			?					
CPb48	Derbya sp.			?					
CPb49	Martinia (?) sp.			?					
CPb50	Hemiptychina (?) (cf. H. orientalis) . . .			?					
CPb5I	Notothyris willisiana GIRTY.			?					
CPb52	Orthotichia (?) sp.			?					

CPb53	Spirifer blackwelderi GIRTY.			?					
CPb54	Orthothetes armenianus				?	?	?		
CPb55	Dalmanella indicus				?	?	?		
CPb56	Productus punctatus				?	?	?		
CPb57	Productus sumatrensis var. palliatus . . .				?	?	?		
CPb58	Productus semireticulatus var. bathykolpos SCHELWIEN.			x					
CPb59	Productus semireticulatus var. palliata KAYS.			x					
CPb60	Productus sumatrensis F. ROMER.			x					
CPb6I	Productus longispinus SOWERBY.			x					
CPb62	Productus subplicatilis FRECH.			x					
CPb63	Productus aculeatus MARTIN var.			x					
CPb64	Productus mongolieus DIENER.			x					
CPb65	Productus intermedius ABICH. var. nov. lopingensis FRECH.			x					
CPb66	Productus cf. abichi WAAG.			x					
CPb67	Productus kiangsiensis KAYS.			x					
CPb68	Richthofenia sinensis WAAG.			x					
CPb69	Lyttomia richthofeni KAYS.			x					
CPb70	Dalmanella (Orthis) subquadrata nov. nom. FRECH.			x					
CPb7I	Enteles kayseri WAAG.			x					
CPb72	Orthothetes circularis nov. nom. FRECH. .			x					
CPb73	Streptorhynchus subplargonatus nov. nom. FRECH.			x					
CPb74	Meekella kayseri JAEKEL.			x					
CPb75	Hustedia grandicosta (Davidson) HALL. . .			x					

CPb76	Terebratula hastata SOWERBY.			x					
CPb77	Strophalosia cf. horrescens VERNEUIL. . .			x					
CPb78	Strophalosia poyangensis KAYS.			x					
CPb79	Chonetes sp. aff. C. flemingi			?					
CPb80	Hemiptychina sp. aff. H. orientalis			?					
CPb8I	Productus costatus SOW.								
CPb82	Chonetes hardrensis PHILL.								
CPb83	Spirifer duplicicosta PHILL.	?	?	?					
CPb84	Spiriferina cristata SOW. var. octoplicata								
CPb85	Marginifera sp.			?					
CPb86	Squamularia (cf. S. perplexa) GIRTY. . . .			?					
CPb87	Spirifer bisulcatus SOW.	?	?	?					
CPb88	Spirifer (Martinia) glabra MART.	?	?	?					
CPb89	Orthothetes crenistria PHILL.	?	?	?					
CPb90	Productus giganteus	?	?	?					
CPb9I	Productus indicus FRECH.			x					
CPb92	Productus lineatus FRECH.			x					
CPb93	Dielasma sp. (cf. D. elongatum)						x		
	(c) GASTROPODA								
CPcI	Pleurotomaria (Mourlonia) cayeuxi MANSUY.	x							
CPc2	Pleurotomaria (Mourlonia) wildeni MANSUY.		x						
CPc3	Pleurotomaria (Mourlonia) sarauti MANSUY.		x						
CPc4	Pleurotomaria multicarinata MANSUY. . . .		x						

CPc5	Pleurotomaria (Worthenia) margaritifera MANSUY. . . .		x						
CPc6	Pleurotomaria (Worthenia) constantini MANSUY.		x						
CPc7	Microdonia imbricata MANSUY.		x						
CPc8	Turbinilopsis sinensis MANSUY.		x						
CPc9	Naticopsis margheritii MANSUY.		x						
CPcI0	Murchisonia laevigata MANSUY.		x						
CPcII	Bellerophon tennifascia DE KON.		x						
CPcI2	Naticopsis cf. piriformis MANSUY.				x				
CPcI3	Littorina (Eunema)			?	?				
CPcI4	Bellerophon sp. undt.						x		
CPcI5	Euomphalus sp.			?					
CPcI6	Loxonema walciodolense DE KON.	?	?	?					
CPcI7	Macrocheilus cf. intermedius DE KON. . . .	?	?	?					
CPcI8	Naticopsis cf. globulina DE KON.	?	?	?					

(d) BRYOZOA

CPdI	Fenestella perelegans MEEK.	x							
CPd2	Polypora megastoma DE KON.	x							
CPd3	Geinitzella sp.		x						
CPd5	Geinitzella crassa LONSDALE.				x				
CPd6	Stenopora cf. crassa LONSDALE.			?	?				
CPd7	Fenestella			?	?				
CPd8	Septopora biserialis SWALL.			x	x				

CPd9	Polypora fastuosa DE KON.	x								
CPdIO	Fistulipora minor M'COY.	x								
CPdII	Geinitzella chinensis GIRTY.			?						
CPdI2	Batostomella meekana GIRTY.			?						
CPdI3	Fistulipora waageniana GIRTY.			?						
CPdI4	Macroporella		?	?						
CPdI5	Rhombopora lepidendroides MEEK.			x						
CPdI6	Fistulipora tuberosa KAYS.		?	x						
	(e) CEPHALOPODA									
CPeI	Glyphioceras sp.	x								
CPe2	Orthoceras sinuatum MANSUY.		x							
CPe3	Pleuronautilus orientalis KAYS.			x						
CPe4	Pleuronautilus mingshanensis KAYS.			x						
CPe5	Orthoceras cf. cyclophorum WAAG.			x						
CPe6	Orthoceras bicinctum ABICH.			x						
	(h) TRILOBITA									
CPhI	Phillipsia sp.			?						
CPh2	Phillipsia obtusicauda KAYSER.			x						
CPh3	Phillipsia kansuensis LOCZY.			?						

	(f) LAMELLIBRANCHIA								
CPfI	Schizodus malani MANSUY.		x						
CPf2	Astartella orientalis MANSUY.		x						
CPf3	Astartella cristata MANSUY.		x						
CPf4	Leda (Nuculana) praeacuta WAAG.sp.						x		
CPf5	Schizodus pinguis WAAG.						x		
CPf6	Schizodus compressus WAAG.						x		
CPf7	Pleurophorus cf. acute-plicatus WAAG. . .						x		
CPf8	Pleurophorus subovalis WAAG.						x		
CPf9	Pseudomonotis radialis PHILL.						x		
CPfIO	Nuccula beyvichi						x		
CPfII	Allerisma cf. subelegans MEEK.						x		
CPfI2	Edmondia cf. nebrascensis GEIN.						x		
CPfI3	Edmondia tiesseni n. sp.						x		
CPfI4	Pecten alberti						x		
CPfI5	Aviculopecten coxanus						x		
CPfI6	Aviculopecten coxanus var. sinensis . . .						x		
CPfI7	Posidonomya becheri	x							
CPfI8	Schizodus sp. (cf. S. curtus)	?							
CPfI9	Schizodus rotundatus BRONN.					?	?		
CPf20	Aviculopecten M'coyi MEEK & HAYDEN. . . .			x					
CPf21	Pinna confutsiana KAYS.			x					
CPf22	Aviculopecten (?) richthofeni GIRTY. . . .						x		

CP

	(g) ANTHOZOA								
CPgI	Favosites ellipticopora MANSUY.		x						
CPg2	Lithostrotion loatiensis MANSUY.		x						
CPg3	Heliophyllum vesiculosum MANSUY.		x						
CPg4	Syringopora sp.		x	?					
CPg5	Lonsdaleia indica WAAG & WENTZ.			x					
CPg6	Zaphrentis sp.			x					
CPg7	Amplexus sp.			x					
CPg8	Lonsdaleia cf. virgalensis WAAG & WENTZ.			x					
CPg9	Lonsdaleia sp.				x				
CPgI0	Zaphrentis beyrichi	x							
CPgII	Pachypora cf. jabiensis WAAG.			?	?				
CPgI2	Syringopora ramulosa GOLDF.	x							
CPgI3	Diphyphyllum simplex	x							
CPgI4	Thysanophyllum longiseptatum n. sp.	?	?	?					
CPgI5	Heterocaninia	x							
CPgI6	Zaphrentis delanouei M. E. & H.	x							
CpgI7	Zaphrentis guerangeri M. E. & H.	x							
CPgI8	Zaphrentis spinulosa M. E. & H.	x							
CPgI9	Lonsdaleia aff. salinaria WAAG.	x							
CPg20	Michelinia favosa GOLDF.	x							
CPg2I	Battersbyia n. sp.	x							
CPg22	Lonsdaleia chinensis GIRTY.			?					
CPg23	Michelinia microstoma nov. nom.				?	?	?		
CPg24	Lonsdaleia omiensis n. sp.	?	?	?					
CPg25	Lophophyllum proliferum M'CHESNEY.			x					

CPg26	Lonsdaleia floriformis	x							
CPg27	Lonsdaleia papillata FISCH.	x							
CPg28	Lonsdaleia waageni FRECH.			x					
	(z) FLORA								
CPzI	Calamites (?)			?	?				
CPz2	Rhabdocarpus densus SCHENK.				?	?			
CPz3	Calamites cf. leioderma GUTBIER.			?	?				
CPz4	Lepidodendron oculus-felis ABBADO.			?	?				
CPz5	Lepidodendron gandryi RENAULT.			?	?				
CPz6	Stigmaria ficoides STERNBERG.			?	?				
CPz7	Cordaites principalis GERMAR.			?	?				
CPz8	Poacordaites sp.			?	?				
CPz9	Cordaicarpus cf. ellipticus STERNBERG. . .			?	?				
CPzI0	Sphenopteris tennis SCHENK.			?	?				
CPzII	Sphenopteris orientalis ABBADO.			?	?				
CPzI2	Sphenopteris regularis ABBADO.			?	?				
CPzI3	Sphenopteris alata STERNBERG.			?	?				
CPzI4	Sphenopteris latifolia BRON.			?	?				
CPzI5	Pecopteris recta ABBADO.			?	?				
CPzI6	Taeniopteris multinervis WEISS.				x				
CPzI7	Taeniopteris tennis ABBADO.			?	?				
CPzI8	Taeniopteris curvinervis ABBADO.			?	?				
CPzI9	Asterotheca crassa ABBADO.			?	?				

CPz20	Annularia sp.			?	?				
CPz2I	Lepidodendron emarginatum ABBADO.			?	?				
CPz22	Lepidophloios laricinus STERNBERG.			?	?				
CPz23	Lepidophloios chinensis ABBADO.			?	?				
CPz24	Sigillaria fogolliana ABBADO.			?	?				
CPz25	Sigillaria plana ABBADO.			?	?				
CPz26	Sigillaria polymorpha ABBADO.			?	?				
CPz27	Sigillaria oculus-felis ABBADO.			?	?				
CPz28	Odontopteris reichiana GUTB.			?	?				
CPz29	Callipteridium gigas GUTB.			?	?				
CPz30	Pecopteris cyathea SCHLOTH.			?	?				
CPz3I	Sphenophyllum oblongifolium GERM.			?	?				
CPz32	Plagiozamites planchardi BRR[illegible].			?	?				
CPz33	Annularia s ttellata SCHLOTH.			x	x				
CPz34	Neuropteris flexuosa STERNB.			?	?				
CPz35	Neuropteris scheuchzeri HOFFM.			?	?				
CPz36	Pecopteris arbonescens SCHLOTH.			x	x				
CPz37	Callipterium orientalis			?	?				
CPz38	Lepidophyllum sp.			?	?				
CPz39	Samaropsis affinis SCHENK.			?	?				
CPz40	Pterophyllum carbonicus SCH[illegible].			?	?				
CPz4I	Calamites cistii BRONG.			x	x				
CPz42	Annularia longifolia BRONG.			?	?				
CPz43	Calamites suckowii BRONG.			?	?				
CPz44	Cordaites borassifolius UNG.			?	?				
CPz45	Lepidodendron obovatum STERB.			?	?				

CPz46	Sigillaria brardii BRONG.			?	?				
CPz47	Archaeopteris n. sp.			?	?				
CPz48	Lonchopteris n. sp.		.	?	?				

···TRIASSIC - JURASSIC.···

(1) General Remarks.

Rocks of indisputable Mesozoic age are known in Northern, Western and S.W. China. In Northern China, they are chiefly distributed in Northern Shan-si, Western Shan-tung and probably N.W. Chi-li. They consist of shallow water deposits containing thick seams of coal. The plant remains and a few species of fishes that have been gathered from these Mesozoic rocks generally indicate Jurassic age. It is uncertain as to whether Trias also occur in association with the Jurassic in Northern China. Presumably the upper part of the massive sandstone series that overlies the Shansian system with apparent conformity belongs to the Triassic.

In the Nan-shan region, N.W. China, coal bearing Mesozoic rocks may occur, but their age has not been definitely determined.

In the Red Basin of Su-chuan and the adjoining regions such as the middle Yang-tze district, the Mesozoic group is well developed and magnificently exposed; but the stratigraphical succession has not been systematically worked out. As far as may be gathered from the available information, here the Mesozoic rocks mainly consist of sandstones, shales and marls with subordinate beds of limestones, and seams of gypsum, rock salt and coal. The nature of the junction between the Trias and the Jurassic in these regions is not definitely known, but it appears to be locally unconformable. The Jurassic beds merge upwards into a massive red sandstone, the age of which has not been determined.

In Eastern Yun-nan, S.W.China, the sequence of the Triassic formation has been worked out by Dr. Deprat who divides it into three stages. The lower stage essentially consists of marls and sandstones; the middle stage is predominantly calcareous; the upper stage is again a series of marls and sandstones. The Triassic base was observed by Deprat in one instance near Tsin-shouei-tang, resting unconformably upon the permian limestone; elsewhere in Eastern Yun-nan, the Triassic strata are broken up in an extraordinary manner due to overthrusting, ~~[illegible]~~, and therefore the natural junction between the Triassic base and the older rocks has not been observed by the same author. In Eastern Yun-nan Jurassic rock has not been discovered. From the study of the structure of the same region, we have reason to believe that the Jurassic rocks probably have been entirely removed through the processes of denudation if ever existed.

In the province of Kwei-chou, S.W. China, Leclere mentions a Jurassic dolomite resting upon the Rhaetic coal bearing series. The stratigraphical details, however, are not known.

During the transitional period from the palaeozoic to the Mesozoic in China, there seemed to be a wide-spread and far reaching change of physiography and physiographical conditions. The change is not, as a rule, represented by a sharp contrast in lithology between the palaeozoic and the

Mesozoic deposits. The same change at the same time does not appear to have prevailed over an area which is so wide as to enable us to recognize the advent of a new period. In one district there might be continual sedimentation without notable break, while in the neighboring region the palaeozoic floor might be lifted above the surface of the palaeozoic waters, and exposed to subaerial denudation. In view of such circumstances we cannot readily draw a definite plane to separate the uppermost palaeozoic from the lowest Mesozoic. For this reason the term "permo-mesozoic" has been used by some geologists for indicating the rocks formed during this transitional period from the palaeozoic to the Mesozoic era.

According to Suess, at the close of the palaeozoic era, a Mediterranean came into existence in Central Asia. He gives this inland sea the name "Tethys"[139] which separated the Angara Continent in the north from the Gondwana land in the South. Willis accepts this view and tentatively regards the Permo-Mesozoic strata in Northern China, i.e. the area lying to the north of the latitude of the Tsing-ling-shan, as belonging to the Angara series.[139] The ? Mesozoic formation occurring in the Nan-shan region is likewise considered by Obrutchov as the presentative of the Angara formation. This hypothesis is supported by the fact that the Jurassic flora of northern China is closely related to that of Siberia.

The Chinese Triassic fauna, particularly the Middle Trias, has a strong affinity to that of the Tirol region and of the Muschelkalk of Germany. Gastropods and lamellibranchs predominate. Cephahopods and crinoids are also represented. Brachiopods are rare. Naticopsis, Undularia, Myophoria elegans, M. Szechenyi, Terquemia difformis, Halobia, Encrinus liliiformis etc. are the characteristic forms. The Chinese Jurassic rocks have yielded a rich flora which has a strong affinity to that of the Angara series; podozamites lanceolatus, Asplenium Whitbyensis, are found nearly in all the regions where Jurassic rocks occur.

(11) Field Observations.

(The full names of the fossils mentioned under this heading are found in List No. 4.)

S.W. China.

Eastern Yun - nan.[16]

The Triassic formation occurs in a large band or an elongated basin in the south eastern part of eastern Yun-nan, running between A-mi-tcheou and Mong-tseu, and extending in a N.N.E. direction. The region lying between Kwang-si-tcheou and Lou-leang is largely occupied by the Triassic deposits. Further N.E., the Triassic band extends into the Province of Kwei-chou. It is bounded both on the north-western and the south-eastern sides by faults of great magnitude, throwing the Triassic down against Permian and Carboniferous. This sunken block of the Triassic strata is itself cut into rectangular blocks by a net-work of faults which are particularly notable in the Mong-tseu district where the Upper

Carboniferous and the Lower Permian limestones are divided up in the shape of large angular pigeon-holes, many of which retain the Triassic sediment. Towards the east, in the direction of Kwang-si-tcheou, in the district of Tchong-ho-yun and on the northern boundary of the Ming-kien-shan, this block structure of the upper carboniferous and the Lower Permian limestone compartments lying in contact with the deeply sunken Triassic compartments, has been carefully described and mapped by Deprat. I need not repeat the detailed description here.

Towards the north-east of Mi-leu, between the sub-prefecture of the same place and that of Kwang-si-tcheou, the country is largely covered by the Triassic rocks which continue to run in a N.N.E. direction towards Tou-tza. In the Hon-keuou district, the contact between the Trias and the palaeozoic is again an abnormal one; but here it is no longer a fault, but is a thrust; large mass of palaeozoic rocks being pushed upon the Triassic strata.

The following records of observations made by Deprat ~~will~~ give us some idea of the general stratigraphical succession of the Triassic rocks in eastern Yun-nan. He divides the Trias in this region into three stages, viz., upper, Middle and Lower

(a) Lower Trias. In the vicinity of Ta-shouei-tang, a village situated 14 K.M. N.W. of Mi-leu, Deprat observed a series of red sandy rock (psammites) resting unconformably upon a gray Permian limestone (V1). In the Argillaceous and the marly layers which are intercalated with the sandy rock, Deprat discovered the following fossils :-

TJA1, TJb1, TJG1.

The occurrence of these fossils, and the stratigraphical relation between the sandy rock and the underlying permian, have led Deprat to conclude that the said sandy rock represents the basal part of the Lower Trias. He further states that the upper part of the Lower Trias is well exposed in the heights of Shoui-tsin, near Ngas-tseu and in the hillocks to the east of Ngaa-tsue (see section No.59). Here Deprat has made out a conformable sequence of Lower Triassic and a part of the Middle Triassic rocks as follows :-

Middle Trias.	t. 17.	Marly limestone with TJb2	
	ta 16.	A series of greenish sandstone	
	t. 15.	Limestone - marl	
	t. 14.	Yellow marl	
	t. 13.	Yellow marly shale	
Lower Trias. (Tla)	12.	Yellow coare sandstone	15 m
	11.	Blue scaly marl	10 m
	10.	Brown-red scaly marl.	25 m
	9.	Bands of fossilferous sandstones. . .	10 m
	8.	Yellow pulverent marl with. . . . . . . TJb1, TJa1, TJb3.	22 m
	7.	Fissile yellow sandy rock (psammites) with. . . . . TJz1, TJz2.	3 m

	6. Yellow marl very fissile and scaly with fossils as in 8...	15 m
	5. Fine-grained yellow argillaceous sandstone	8 m
	4. Yellow marl.	
	3. Chocolate scaly marl.. ...	5 m
	2. Yellow pulverent marl. ...	2 m
	1. Yellow sandy rock (psammites) with fossils as in 7. ...	10 m

(Unconformity) --

Permian (Limestone (V1).

Towards Siao-sin-tien, in the Mi-leu district, the lower Trias with Myophoria, Teaniopteris, Dyctyophyllum sp. etc., attains a greater thickness than the section mentioned above. There the lower micaceous sandy series alone is more than 150 m thick and a seam of coal is present in the zone t1. which is not represented in the hills of Ngao-tseu.

To the north of the lake Tsin-shouei-tang, in the district of Mong-tseu and Da-mi-tchou, the Lower Trias is separated by red "psammites" from the underlying permian basalt, "cinerite" and tuff; and passes upwards into the Middle Trias through insensible gradation. The rocks are composed of alternating beds of marls and sandstones.

(b) Middle Trias - Deprat gives the following generalized section of the Middle Triassic rocks in eastern Yun-nan :-

passage beds from Upper to	(t1V. Brown manganiferous shale of Tou-pi with large Halobias (TJb4), Ammonite (TJd1), TJd2, etc. ...	5m

Middle Trias	tIII.	Argillaceous limestone with TJd3, TJd4, TJd5	10 m
	t II.	"Complex" formation of sandstones, shales and marls with coal seams	150 m
	t I.	Marl of Tchong-ko-lo with..	120 m
Middle Trias	t,,,	Coarse sandstone and quartzite with "phtanites" of Lan-ni-pe.	
	t,,	7. Argillaceous limestone.	25 m
		6. Limestone.	200 m
		5. Bluish limestone with yellow layers... ...	15 m
		4. Bands of marly limestone of Lo-se-tang... ...	30 m
	t,	3. Coarse grits and quartzite of Ngan-pien-chao. ...	100 m
		2. Variegated marl. ...	25 m
		1. Variegated marly shale..	70 m

In the district of A-mi-tcheou, Lantenois has distinguished three lithological divisions of the Triassic rocks. They are as follows :-

(3). Sandstones and shales of Lan-ni-pe.

(2). Blue gray massive limestone of Ta-tshoung

(1). Versicoloured sandstones and shales of Ien-fen-tshoung.

Deprat states that, the series (1) is equivalent to 1 & 2 of the t, zone; (2) is probably in part equivalent to 6 of the t,, zone; and (3) = t,,,.

~~(c) Upper Trias –~~ In eastern Yun-nan the Middle ~~Upper~~ Trias is distributed in th e neighbourhood of A-mi-tcheou, the vicinity of Mong-tseu, the plateau of Tchong-ho-yun, and between the Ming-kien-shan fault and th e fault which passes A-mi-tcheou, Pong-pou, Tchou-yuen. (c) Upper Trias – The general sequence of the upper Triassic rocks in eastern Yun-nan ~~these districts~~ is described by Deprat as the following :-

Upper Trias.	TVll.	Arkose sandstone with intercalations of coal seams and marly layers. Plant remains occur.	300 m
	tVl.	Soft rosy marl with TJd6, TJd7 ...	80 m
	tVa.	Gray-green scaly marl with TJd8, etc.	130 m
	tV.	Gray and green marls with TJC18 to TJb20.	100 m
Passage beds.	tlV.	Brown soft marly shale with TJdl.	20 m
	tll.	Brown sand & Argillaceous limestone with TJd3, TJd4, TJd5, TJd9, TJdl0.	15 m

The entire sequence of the Upper Trias is well exposed near the Tou-pi pass at Ki-ou-ke on the main road running between He-ou-tchin & Ma-tchi-tchao.

Kwei-Chou.

E. Koken has described a fauna which is reported to have been derived from Si-tsi-san, Tchin-ngai, in the Province of Kwei-chou. From the fact that yellowish-gray micaceous marl, small grains of red-brown ironstone and calcareous material are attached to the fossils, Koken judges the containing rock of the fauna to be an impure limestone. Koken says that he is unable to find out the locality on any map of China. The writer has also failed to locate any District bearing the name "Tchin-ngai" through-out the Province of Kwei-chou; but he thinks that it is probably the wrong spelling of "Tchin-ngan" (about lat. 28° 20' N. long. 107° 30' E.) The fauna consists of the following species :-[276]

TJc o to TJc17, TJb21, TJa3, TJa4, Bryozoa, etc.

Leclere reports the occurrence of a dark hard limestone in the neighbourhood of Sha-tze-kang, near Kwei-yang. He regards this limestone as Lower Triassic formation because of the presence of certain Cephalopods and small Gastropods. Among the Cephalopods, Douville mentions a form which, according to him, is almost identical to Lecanites psilogyrus WAAGEN. The latter occurs in the lower Ceratite limestone of Indo-China.[45,264]

At Kiang-ti-ho (lat. 24° 53' N. long 104° 35' E.) in a micaceous clay shale, Leclere found plant remains which, according to Zeiller, resemble Glossopteris indica, Cladophlebis roesserti indicating Upper Triassic age.[46]

On the left bank of the Blue River, Leclere observed yellowish cavernous dolomitic limestone resting upon the "Rhaetic coal bearing series".[46] The same limestone is exposed in many districts in the province of Kwei-chou, forming characteristic plateaus. A.S.F.Bourne[2] describes a limestone plateau lying on the N.W. of Jao-mong and forming the divide between the provinces of Kwang-si and Kwei-chou. Loczy and Richthofen also speak of the conspicuous features of the limestone mountains in these provinces.[61] Leclere believes that it attains a thickness of more than 200 meters. In the district of Iao-pou, south of Tchen-ming, the upper part of th e limestone yields pleuromya and Gastropods (Hologyra?). Douville regards th em as Jurassic forms.

S.W. Su-chuan.

At Tai-pin-tchang (lat. 27° N. long 101° 45' E.) Leclere found plant remains which, according to Zeiller, consist of the following species :-

TJZ3 to TJz9.

To the east of Tai-pin-tchang, in the district of Tang-tang and Shuei-tang-pu, Yamada makes out the following succession of rocks and has obtained a few fossils :- (see section No. 51)

(Trias.)

6. Red and yellow sandstones and shales.
5. Limestone.
4. Red & green sandstone and shales with coal seams containing fossil plants TJz10 to TJz12.

3. Diabase and its tuffs.
2. Limestone "(Permo-Carboniferous)".
1. Sandstone.

At Tschung-tjen, (the writer is unable to locate the exact position of this place) Loczy obtained a fauna from a carbonaceous limestone, which consists of the following species :-

TJc18, TJc6, TJC14, TJb22, TJb12, TJb24, TJb2, TJb25, TJb23, TJa5, TJe3, TJel.

In the neighbourhood of Ning-yuan-fu and to the north of it, A.F.Legendre observed a plateau-forming limestone being overlain and underlain by sandstones. Failing to find any fossil in this limestone, Legendre is unable to determine the age of it, but he definitely states that the sandstone that overlies the limestone is the same formation as that covering the red basin of Su-chuan.[48]

Western China.

The Red Basin of Su-chuan.

Abendanon describes the succession of the rocks forming the Great Red Basin of Su-chuan as the following[1] :-

Jurassic?	7.	Variable bands and layers of reddish brown ferruginous clay-rock and bright red sandstone. The latter is largely aeolian deposit. -------- probably --- --- --- ---	2000 m
	6.	Shaly marl.. --- --- ---	50 m
Trias ?	5.	Sandstone with intercolated clay shales which contain 3 to 4 seams of coal, each seam is about 1 m. thick. The upper part of the sandstone yields TJz13 --- ---	?
	4.	Calcareous shale and argillaceous limestone ---	400 m

(3. Red-brown clay-rock & bright coloured
)
(sandstone containing seams of rock salt, which are especially abundant in the vicinity of Kuei-chou-fu, Yen-tschang & Tze-liu-djin --- --- --- 300 m

The series (3) is believed by Abendanon to be underlain by a massive limestone which appears to be the Wu-shan limestone of Willis & Blackwelder. Since this limestone is not exposed inside the basin it is not mentioned here. By far the greatest part of the basin is covered by the uppermost series (7). Immediately to the north of Kwang-yuan-hsien, on the border of the Red Basin, Richthofen makes out the complete sequence of the rocks as the following[94] :- (see section No33)

B.	6. Thick-bedded soft green sandstone ------	500 ft.
	5. Shale with subordinate red sandstone ---	600 ft.
	4. Yellow sandstone with shaly strata ---	1000 ft.
	3. Massive yellow conglomerate including pebbles of limestone, hard sandstone, becomes coarser towards the base. ...	300 ft.
	2. Plant bearing gray shale and soft sandstone containing two seams of coal, each seam 3 to 4 feet thick. Among th e plant remains Schenk identified TJzl.	
	1. Thick-bedded sandy and shaly rock of yellow and gray colour. The lower part of this series probably contains coal seams ---	1000 ft.

A. White-gray cloddy limestone which is followed downwards by a yellow dolomite, and then a massive limestone. A thin-bedded green and white limestone lies at the base.

The following section is described by Richthofen, showing the succession of rocks exposed in the anticlinal ridge below Tshang-shou-hsien, in the eastern part of the basin.[129]

8. Red sandstone; the sand grains are often coated by black metallic oxide.
7. Firm whitish and brownish sandstone.
6. A coal seam.
5. Firm whitish and brownish sandstone.
4. A coal seam.
3. False-bedded soft sandy strata.
2. Thin-bedded limestone.
1. Highly compressed gray limestone strata, traversed by white veins.

Near Chung-king (lat. 29° 40' N. long, 106° 30' E.) the species TJz14 has been obtained from a shale.[44,300]

At Chin-gang-lin, Pun-hsien, TJz25, TJz21, TJz26 occur in a dark gray micaceous argillaceous sandstone.[298]

At Ta-shi-gu, Ba-hsien, Chung-king-fu, TJz25, TJz27 occur in a dark shale.[298]

Near Kwang-yuan-hsien, on the northern border of the Red Basin, Loczy found the following species in a dark gray shale.[287]

TJz21, TJz28 to TJz35.

The Kuei-chou basin & the adjoining districts.

The Kuei-chou basin lies between the Great Red Basin of Su-chuan and the Gorge district of the middle Yang-tze. In this basin Willis & Blackwelder distinguish a series of rocks which they call the Kuei-chou series.[185] They believe that the lowest stratum of this series unconformally overlies the Wu-shan limestone; but the junction between the Wu-shan limestone and the Kuei-chou series was not observed by them.

Willis & Blackwelder divides the Kwei-chou series into two parts --- (1) The lower part consists of reddish brown sandstones and hard shales; (2) the upper part consists of gray sandstones, shales with occasional seams of limestones and layers of coal. The total thickness of the Kuei-chou series in the Gorge district of the Yang-tze is estimated by Willis & Blackwelder at about 1,000 ft.

Richthofen describes the complete sequence of the rocks forming the Kuei-chou basin as the following :-[130] (see section No38)

9. Massive red sandstone. ... ... at least 1500 ft.
8. Blackish yellow sandstone of soft red strata. about 2000 ft.
7. Red sandstone with yellow calcareous and marly intercalations ... ... 700 ft.
6. Gray thick-bedded sandstone.. ... 150 ft.
5. Sandstone and black shale with 3 coal seams. 300 ft.
4. Coarse thick-bedded soft sandstone, partly conglomeratic. ... ... 250 ft.
3. Sandstones and shales with 4 thin coal seams. 250 ft.

(Kuei-chou series ?)

(2. Alternation of sandstone & limestone, siliceous
)
(yellow dolomite and yellow & black shale. ... 150 ft.
)
(1. Red shaly and sandy strata.

Pumpelly & Richthofen obtained fossil plants in the Kuei-chou basin. They do not mention the exact locality and horizon from which each species was collected. Presumably the fossils occur in association with the coal seams. The collective flora consists of the following species :-

TJz15 to TJz24.

S. E. CHINA.

The occurrence of Jurassic rock in the Province of Kiang-si is indicated by the presence of a Jurassic flora in the districts mentioned below. The flora is derived from a dark shale in the mines.[298] (Coal mine?.)

1. At San-chia-chung, An-yuan, Ping-shang-hsien.)
2. At Kau-kun, Ping-shang-hsien.) TJz21 occurs.
3. At Chung-chia-fang, I-chuen-hsien.)
4. At Sha-shi-chiai, An-yuan, Ping-shang-hsien. (TJz21 & TJz36 occur.
5. At Ssu-lu-pu, Hsin-an-hsien, TJz37, TJz38 occur.
6. At Lias-chia-shan, Zon-chien-hsien, TJz39 occurs.

NORTHERN CHINA.

Shan-tung.

The occurrence of Mesozoic deposits in the province of

Shan-tung was first discovered by Potonies who identified a Jurassic flora derived from that Province. Lorenz mentions three places in Shan-tung, where Mesozoic rocks are known to him[62] --- (1) Fang-tse, South of Wei-hsien; (2) Putschi, Southern Shan-tung; (3) Tsing-ko-tschwang in the Sin-tai basin. The rocks are generally composed of compact and flaggy sandstone with relatively unimportant coal seams. The boundaries of these Jurassic outliers in Shan-tung are still unknown, Lorenz ~~says that he~~ is inclined to hold ~~take the view~~ that the Mesozoic deposits pass~~es~~ upwards into the Tertiary without notable break; the retreat of water from the Province was relatively a recent event. This, of course, is an open question.

Dr. S. Woodward has described a few well preserved species of fishes obtained from Poh-tze, near Layang-hsien. The fishes, according to the same author, indicate ? Lower Jurassic age. The writer is unable to locate the district bearing the name Layang-hsien, but thinks that the name Poh-tze refers to the same locality as Putschi ~~of~~ referred to by Lorenz.

Wada has found plant remains in a gray argillaceous sandstone in the coal mines of Fang-tu, Wei-hsien. Among the remains, Yokoyama identified the following species[298] :-

TJz25, TJz40, TJz21.

These Jurassic forms prove conclusively that Richthofen's original announciation of the age of the Wei-hsien coal bearing rocks is erroneous, for he regards it as Carboniferous.[95]

Northern Shan-si & Northern Chi-li.

In the valley of Sang-kan-ho and the upper part of the Hu-to-ho valley, Richthofen mentions Jurassic rocks being unconformably underlain by the "Sinisian". He observed the exposure of the Jurassic in five localities[96] -- (1) Fan-shan-pu, (2) N.E. of Pau-ngan-tshou, (3) near Hsi-ying-tsze and Tumulu (on the southern Mongolian border), (4) near Orr-shi-san-hau, (5) the west of Ta-tung-fu. The rocks mainly consist of sandstones with subordinate intercalation of shales. In the localities (2) (3) (5), coal seams occur; and in Tumulu and Ta-tung-fu, plant remains were discovered. From the material derived from the Ta-tung-fu coal field, Schenk has identified TJz45, TJz46; and from that derived from Tumulu, the same Palaeontologist recognizes TJz28, TJz13, TJz21, TJz45 to TJz51.

At Pau-ngan-tshou, the coal bearing sandstone is overlain by porphyrite and porphyritic conglomerate.

From Hung-Mei-tshang to Tshai-tang, near the Nan-kou mountain, Richthofen followed a mighty succession of coal bearing rocks aggregating to a thickness of 15,770 ft. He describes it as the following :-

D. Porphyrite & Porphyritic conglomerate.

(Jurassic ?) C. ((e) Dark sandstone and shale with bituminous coal seams. ... 500 ft.
((d) Productive series with anthracite. 600 ft.

(Jurassic ?) C.	(c) Red clay-rock, almost unstratified ...	2000 ft.
	(b) Chiefly black or gray slates and sandstones with intercalated quartz conglomerate and anthracite seams ---	290 ft.
	(a) Principally gray sandstone which contains irregular patches of mica flakes arranged vertically, green tuffaceous rock and anthracite seams...	2200 ft.

(unconformity) ? --

(Pre-Sinisian ?)	B. Limestone with flints and quartzites, the latter predominate in the lower part of the series	5520 ft.
	A. 3. Dark green sandstone.	
	2. Green schist.	
	1. Grey sericitic slates, often contorted & quartz-veined.	

At San-yu in the Tshai-tang basin, Pumpelly obtained the following fossil plants from a brown sandstone[284]:-

TJz52 to TJz54.

One of the above-mentioned species also occurs in the Tin-Kia-po flora obtained from southern Shan-si and described by Brongniart.[258]

(III) Correlation.

(a) Lower Trias.

It is true that the fossils that have been found in Eastern Yun-nan in the Lower Triassic rocks (p217-) do not conclusively prove the Lower Triassic age, but the fact that they underlie the incontestable Middle Trias defines the stratigraphical position of the psammites beyond any doubt.

The limestone of Sha-tze-kang (p221) is compared by Douville with the lower ceratite limestone of Indo-China; accordingly it may be referred to the Lower Trias.

The coal bearing series (4) of Tang-tang (p222) overlies a volcanic series which is underlain by permo-carboniferous limestone according to Yamada. In eastern Yun-nan, we know that there is an extensive volcanic series which represents a part of the upper permian, and no other instance of volcanic activity is known during the permo-carboniferous -- Triassic period. Therefore it is highly probable that the volcanic series (3) of Tang-tang represents the Upper Permian; hence the coal bearing (4) is probably of Lower Triassic age. Moreover the flora contained in the same series is according to Yokoyama, comparable with that of the terrestrial Gondwana system; (panchet group ?) the latter is generally regarded as Lower Trias.

The Red-brown clay-rock and sandstone (3) ~~of~~ in the Red Basin of Su-chuan (p224) probably belongs to the Lower Trias, for we have reason to believe its overlying calcareous series belonging to the Middle Trias.

The base of the upper Kuei-chou series (p226) contains a fauna which according to Girty, indicates the uppermost palaeozoic; and from the upper phytiferous beds of the same series Upper Triassic or Lower Jurassic plants such as Nilsonia, Podozamites, Asplenium, etc. have been obtained. Therefore, the rocks lying between the base of the upper Kuei-chou series and the plant-bearing horizon must be referred to the Trias. Exact classification of the Triassic strata being unavailable in the Kuei-chou district, we can only vaguely assign the Lower part of the Upper Kuei-chou series to the Lower Trias.

(b) Middle Trias.

In Eastern Yun-nan, the lower part of the Middle Trias yields Myophoria Szechenyi. This species occurs in association with Terquemia difformis, Myophoria elegans, Encrinus liliiformis at Tschung-tjen (p222); these are well-known Muschelkalk forms of Germany. The fauna of Tchin-ngan (p221) is likewise compared by Koken with that of the Muschel-kalk of Germany and of St. Cassian of South Tirol. In the Himalaya region marine Trias with a pelagic fauna is known; while in southwestern China, the Middle Triassic fauna is almost exclusively represented by shallow water forms. This fact indicates that the open ocean lay to the southwest of China in the Middle Triassic time.

In eastern Yun-nan, Deprat distinguishes two passage zones between the Middle and the Upper Trias. (p218) The establishment of these two zones, as pointed out by Deprat, are less arbitrary than it appears to be. In the zone tlll, the fauna is related to that of St. Cassian Beds; while in the tlV zone, Cephalopods which are also present in the Raibl Beds, begin to appear. Thus the zone tlV in eastern Yun-nan appears to be equivalent to the lowest stage of the Keuper.

The limestone (5) in the Tang-tang section (p222) may be referred to Middle Trias, for it overlies the coal bearing series which we have already assigned to the Lower Trias; and it lies between Argillaceous and Arenaceous beds as in the case of the Middle Trias in eastern Yun-nan.

The Argillaceous limestone (4) exposed in Red Basin of Su-chuan, (p223) is overlain by sandstone and shales. The latter is regard by Abendanon, as Upper Trias on account of the presence of Asplenium argutulum. The underlying limestone is then likely to belong to the Middle Trias. Here again we find that the succession of the rocks is essentially similar to that of the Trias in eastern Yun-nan, i.e.., a calcareous formation lies between Argillaceo-arenaceous formations. In the absence of direct palaeontological evidence, however, the writer considers this correlation as only suggested, not established.

On the northern border of the Red Basin of Su-chuan near Kwang-yuan-hsien, (p225) the limestone (A) is overlain by 1000 ft of sandstones and shales. Above the sandstones and shales, Lower Jurassic plant remains occur. Hence it is not unreasonable to assume the Sandstones and shales to be

Upper Trias, and consequently to regard the limestone A as Middle Trias.

(c) Upper Trias.

The Tai-pin-tchang flora, (p222) is according to Zeiller related to the Trias and Lias of India and the Rhaetic of Europe hence he concludes that the coal bearing series of Tai-ping-tchang belongs to the Rhaetic stage.

Both Newberry and White regard the flora of the Kuei-chou basin (p227) as belonging to the Rhaetic stage; while Schenk considers Nilsonia compta and podozamites lanceolatus as unmistakable Lower Jurassic forms.

Abendanon regards the coal bearing sandstones and shales (5) (p223) as Upper Trias on account of the presence of Asplenium argutatum. The writer suggests that the sandstones and shales (B1) (p224) exposed near Kwang-yuan-hsien probably belong to the Upper Trias on the ground that it is overlain by the Lower Jurassic.

(d) Jurassic.

The flora of Chin-gang-lin, Ta-shi-gu (p225) belongs to the Jurassic according to Yokoyama. The flora of Kwang-yuan-hsien (p225) also belongs to the Jurassic according to Schenk who speaks of the affinity between the Jurassic flora in Siberia and that of Su-chuan.

There is much doubt as to what part of the red sandstones in the Red Basin of Su-chuan should be assigned to the Jurassic.

In all probability the Jurassic formation does not extend to the top of the series, for doubtful cretaceous plant remains[298] and fossilized teeth and jaws of certain Tertiary mammals[284,285] have been found in the Red Basin.

In the Kuei-chou-basin, Richthofen describes a thick sequence of strata (p226). The gray thick-bedded sandstone (6) is regarded by him as the uppermost stage of the Jurassic formation in that region. For what reason Richthofen does so, the writer is unable to find out. But it is certain that his classification is not based on palaeontological evidence.

The occurrence of Jurassic rocks in Kiang-si (p227) and Shan-tung (p228) has been already mentioned. The Jurassic flora derived from these provinces shows close affinity to that of Siberia.

The flora of Ta-tung-fu (p229) is described by Schenk who mentions the presence of the species Baiera angustiloba HEER. This form is also present in the Jurassic flora of eastern Siberia and the Amur district. The Tumulu flora (p229) includes typical Jurassic forms such as Asplenium Whitbyensis, Podozamites lanceolatus, etc. From lithological likeness, Richthofen correlates the coal bearing series of Pau-ngan-tshou with that of the Ta-tung-fu and Tumula; the latter are palaeontologically determined as Jurassic, therefor Richthofen assigns the Pau-ngan-tshou productive measures to the Jurassic.

The coal bearing series of Tshai-tang (p229) is overlain by porphyrite and porphyritic conglomerate which also overlie the coal bearing series of Pau-ngan-tshou. Through this link Richthofen connect the Pau-ngan-tshou coal field with that of Tshai-tang and hence he determines the age of the coal bearing series of Tshai-tang as Jurassic. The Jurassic plant remains obtained by Pumpelly from the Tshai-tang basin prove the correctness of Richthofen's determination, [although he does not mention the fact that Jurassic fossils have been found by Pumpelly.]

L I S T No 4.

FOSSILS FOUND IN TRIASSIC-JURASSIC ROCKS IN CHINA.

Note The reference no. of each species is only used in this thesis for convenience.

Reference No.	Names	Stratigraphical position				Originally described in — (See bibliography)	Mentioned in this thesis in p —
		Lower Triassic	Middle Triassic	Upper Triassic	Jurassic		
	(a) BRACHIOPODA						
TJaI	Lingula meters is TERQ.	x					
TJa2	Coenthyris vulgaris SCHL.		x				
TJa3	Rhynchonella s inens is n. s p. KOKEN.		x				
TJa4	Retzia fuchs i n. s p. KOKEN.		x				
TJa5	Spiriferina s ubfragilis LOCZY.		x				
	(b) LAMELLIBRANCHIA						
TJbI	Myophoria s p.	x					
TJb2	Myophoria s zechenyi LOCZY.		x				
TJb3	Anoplophora s p. undt.	x					
TJb4	Halobia		x				
TJb5	Ps eudomonotis illgrica BITTNER.		x				
TJb6	Pleurophorus s p.		x				

TJb7	Cassianella sp.		x				
TJb8	Myophoria cf. curvirostris SCHL. (?)		x				
TJb9	Myophoria laevigata GOLDF.		x				
TJbIO	Myophoria radiata LOCZY.		x				
TJbII	Nucula cf. excarvata GOLDF.		x				
TJbI2	Avicula bronni ALB.		x				
TJbI3	Daonella indica BITTNER.		x				
TJbI4	Terquemia difformis GOLDF.		x				
TJbI5	Pecten sp.		x				
TJbI6	Gervillia intermedia MANSUY.		x				
TJbI7	Pleuromya (Pamopaea) cf. alberti VOLTZ. . . .		x				
TJbI8	Halobia comata BITT.			x			
TJbI9	Pecten fimbriatus MANSUY.			x			
TJb20	Pseudomonotis plicatuloides MANSUY.			x			
TJb2I	Nucula cf. strigilata GOLDF.		x				
TJb22	Lima chinensis LOCZY.		x				
TJb23	Pleurophorus cf. angulatus MOORE.		x				
TJb24	Myophoria elegans DKR.		x				
TJb25	Myophoria curvirostris SCHL.		x				

(c) GASTROPODA

TJcI	Trochus cf. glandulus.		x				
TJc2	Naticopsis sp.		x				
TJc3	Pseudomelania nodosa		x				

TJc4	Delphinulopsis cainali STOPP.		x				
TJc5	Promathildia sp.		x				
TJc6	Scalaria or Worthenia sp.		x				
TJc7	Hologyra (Naticopsis) declivis KITT.		x				
TJc8	Undularia cf. pachygaster KITT.		x				
TJc9	Undularia cf. escheri KITT.		x				
TJcIO	Worthenia tuberculifera n. sp. KOKEN.		x				
TJcII	Worthenia nuda n. sp.		x				
TJcI2	Pleurotomaria gottschei n. sp. KOKEN.		x				
TJcI3	Coelocentrus moellendorfi n. sp. KOKEN. . . .		x				
TJcI4	Coelostylina cf. conica		x				
TJcI5	Loxonema sp.		x				
TJcI6	Naticopsis signata n. sp. KOKEN.		x				
TJcI7	Entrochus retiformis n. sp. KOKEN.		x				
TJcI8	Loxonema (Promathildia ?) cf. subornata MSR.		x				
	(d) CEPHALOPODA						
TJdI	Trachyceras costulatum MANSUY.		x				
TJd2	Orthoceras multilabiatum HAUER.		x				
TJd3	Clionites zeilleri MANSUY.		x				
TJd4	MEEKoceras yunnanensis MANSUY.		x				
TJd5	Trachyceras douvillei MANSUY.		x				
TJd6	Trachyceras fasciger MANSUY.			x			
TJd7	Megaphyllites lantenoisi MANSUY.			x			

TJd8	Paratibetiles clarkei MANSUY.			x			
TJd9	Trachyceras sinensis MANSUY.		x				
TJdIO	Trachyceras deprati MANSUY.		x				
	(e) CRINOIDEA						
TJeI	Encrinus liliiformis		x				
TJe2	Traumatocrinus sp.		x				
TJe3	Cidaris sp. undt.		x				
	(z) FLORA						
TJzI	Taeniopteris	x			x		
TJz2	Nevropteridium sp. (?)	x					
TJz3	Dictyophyllum exile BRAUN.			x			
TJz4	Cladophlebis raessertі PRESL.			x			
TJz5	Ctenopteris n. sp.			x			
TJz6	Taeniopteris n. sp.			x			
TJz7	Glossopteris indica SCHIMPER.			x			
TJz8	Clathropteris platyphylla GOEPPERT.			x			
TJz9	Anomozamites inconstans BRAUN.			x			
TJzIO	Angiopteridium cf. infarctum FEIST.			?			
TJzII	Carpolithes yamadai sp. YOKOYAMA.			?			
TJzI2	Phoenicopsis ? yamadai n. sp. YOKOYAMA. . . .			?			

TJzI3	Asplenium argutulum HEER.			x	x		
TJzI4	Podozamites distans PRESL.			x	?		
TJzI5	Angiopteridium richthofeni (Angiopteris richthofeni SCHENK)			x			
TJzI6	Cladophlebis petruschinensis (Asplenium petruschinensis HEER)			x			
TJzI7	Rhabdocarpos densus SCHENK.			x			
TJzI8	Nilsonia compta (PHILL) GOEPP.			?	x		
TJzI9	Pterophyllum nathoristi SCHENK.			x			
TJz20	Pterophyllum contigunum SCHENK.			x			
TJz2I	Podozamites lanceolatus (L&H) BRAUN.			?	x		
TJz22	Podozamites emmonsi NEWBERRY.			x			
TJz23	Czekanoskia rigida HEER.			x			
TJz24	Araucaria prodromus SCHENK.			x			
TJz25	Todites williamsonia BRONG.				x		
TJz26	Antholites chinensis n. sp. YOKOYAMA.				x		
TJz27	Carpolithes globularis n. sp. YOKOYAMA.				x		
TJz28	Asplenium whibyensis HEER.				x		
TJz29	Adiantum szechenyi SCHENK.				x		
TJz30	Oleandridium eurychoron SCHENK.				x		
TJz3I	Clathopteris sp.				x		
TJz32	Phyllotheca sp.				x		
TJz33	Anomozamites loczyi SCHENK.				x		
TJz34	Taxites latior SCHENK.				x		
TJz35	Phoenicopsis sp.				x		
TJz36	Phoenicopsis latior YOKOYAMA ?				x		
TJz37	Pterophyllum sp. undt.				x		

TJz38	Nilsonia sp. undt.				x		
TJz39	Cladophlebis sp. undt.				x		
TJz40	Conioptéris hymeaphylloides BRONGN.				x		
TJz4I	Dicksonia sp.				x		
TJz42	Baiera angustiloba HEER.				x		
TJz43	Anomozamites SCHIMPER.				x		
TJz44	Petrophyllum BRONGN.				x		
TJz45	Petrophyllum aequale BRONGN.				x		
TJz46	Podozamites gramineus HEER.				x		
TJz47	Elatides chinensis SCHENK.				x		
TJz48	Pterozamites sinensis NEWBERRY.				x		
TJz49	Sphenopteris orientalis NEWB.				x		
TJz50	Hymenophyllites tenellus NEWB ?				x		
TJz5I	Asplenites rosserti BRONGN.			?	x		

P O S T   J U R A S S I C.

A long geological period extending from the upper Jurassic down to the present day, is poorly represented in China by sedimentary record. The exploration of geologists has so far failed to discover the presence of marine cretaceous formation in that country; and the existing records of geological observations converge to show that such rocks are entirely absent through-out the whole area of China proper. Terrestrial or lacustrine deposits of cretaceous age may exist, but they have not been definitely identified because of the general unfossiliferous nature of the Chinese post Jurassic and prepliocene rocks. Two forms of plants were collected from the Red Basin of Su-chuan, and have been described by Yokoyama who regards them as representatives of Cretaceous flora; but it is doubtful whether we can consider his statement as conclusive.

Tertiary rocks have a fairly wide distribution in China and in places attain a considerable thickness. They are essentially composed of soft red sandstones with occasional layers of shales, marls and conglomerates. In Southern Manchuria and Eastern Yun-nan, the Tertiary formation contains seams of workable coal; in N.W.China, beds of gypsum and rock salt are occasionally found amongst the Tertiary deposits. Lacustrine limestone of ? Tertiary age[17] is known in Eastern

Yun-nan. As a whole, the nature of the deposits suggests that th ey were probably formed in inland waters.

Tertiary rocks in China usually occur in isolated basins between mountains formed by palaeozoie strata. This fact leads the writer to suppose that the major surface features of China, at all events southern China, have not altered ~~to~~ to any extent since the deposition of the soft red sandstone had begun. The most remarkable physiographical change since that time is probably the total disappearance of the inland waters; in their place we now find the red sandstones.

Stegodon, Mastodon, Hipparion, Trogoceras, Rhinoceros, and a large number of other mammals have been found in the Tertiary rocks in China. They indicate upper Miocene or early pliocene age according to Owen and Schlosser.

At the end of the Tertiary period the formation of loess began in Northern China; and it is continued down to the present day. Hills and valleys are often indiscriminately covered by this superficial deposit, representing the last record of Chinese stratigraphy.

Since there is not much to be described about the post Jurassic rocks in China, I shall only mention a few typical formations without strictly referring to their geological age.

(a) Red Sandstone formation.

This formation essentially consists of soft red sandstones with subordinate clays and conglomerates. They are sometimes well-bedded, and sometimes false-bedded or even without any trace of bedding. In N.W.China, in the Nan-shan region, Prjewalski, Loczy, Obrutchov, mention the occurrence of a brownish-red, fine-grained sandstone of friable nature in association with red clays, gypsum and rock salt. This sandstone spreads over a wide area in the valley of the upper Hwang-ho and the valleys between the Nan-shan mountains, and extends to the south of Min-tsou. Above Lan-chou-fu, Kan-su it is deeply cut into by the upper Yellow River, revealing a thickness of over 3000 ft. The usually horizontal stratification of the red sandstone is occasionally replaced by a gentle dip in contrast to the highly folded rocks underlying it.

In Western China, in the Si-shiu ranges, Loczy observed a horizontally bedded Flysch-like sandstone filling up the valleys between the high mountain ranges. The same flysch-like sandstone occurs in Western Yun-nan. In this sandstone Loczy found imperfect specimens of Palaeodictyon and Caulerpites; Schenk regards them as ? Eocene Algea.[287]

The uppermost stage of the Red sandstone in the Red Basin of Su-chuan and in the basin of Kuei-chou, is thought by Abendanon and Richthofen, to be of post Jurassic age.

In the provinces of Hu-nan, Kiang-si, Hu-peh, Ho-nan, red sandstones and conglomerates occur in isolated patches. To those occurring in the province of Hu-nan, Richthofen applies the name "Decke-sandstein".[131]

Fossils that have been discovered in this red sandstone formation generally indicate pliocene age; but some forms are known in the upper Miocene and other are present in the pleistocene fauna in other countries.

The more well-known forms are tabulated below.

Names of fossils.	Names of the Provinces in which they occur.					
	Su-chuan.	Shen-si.	Hu-peh.	Hu-nan.	Ho-nan.	Yun-nan.
Stegodon insignis		x				
Rhinoceros Labereri n.sp. SCHLOSSER.	x	x				
Felis sp. aff. pardus SCHL. ...	x	x	x	x	x	
Aceratherium blanfordi var. hipparionum (KOK) SCHL. ...	x	x				
Hippopotamus sp. indt.	x	x				
Cervavus Oweni KOK...	x	x	x	x	x	
Gazella palaeosinensis SCHL. ...	x	x	x	x	x	
Hyaena sp.	x	x	x	x	x	
Hyaena gigantea SCHL.	x	x	x	x	x	
Mastodon aff. latidens SCHL.. ...	x	x	x	x	x	
Hipparion richthofeni KOK.... ...	x	x	x	x	x	
Trogoceras gregarinus SCHL... ...	x	x	x	x	x	
Hyaena sinensis OWEN.			x			x
Rhinoceros sinensis OWEN.			x			x
Rhinoceros plicidens KOK.			x			x
Tapirus sinensis OWEN.			x			x

(b) The Wen-ho conglomerate.[186]

In the Wen-ho valley, Shan-tung, Richthofen and Blackwelder observed a series of conglomerate overlying the Sinisian limestone. Richthofen calls it the Wen-ho conglomerate. It sometimes attains a thickness of 100 ft. or more. The pebbles of the conglomerate are fairly well-rounded, but angular ones are also present. They are principally composed of the Sinisian limestone, quartzite, cherts, red sandstone and various kind of igneous rocks. Sometimes the conglomerate is firmly cemented and sometimes it is quite loose. The red sandstone pebbles bear more resemblance to the permian sandstone than to the Sinisian sandstone. Similar conglomerate occurs in the Ning-shan basin, S.W. Chi-li.

It is significant that all these conglomerates only occur on the downthrow sides of large normal faults. This fact has led Willis to assume that the conglomerates are the products resulting from the denudation of the fault scarps. From the study of physiography in northern China, Willis determines the age of the normal faults in Shan-tung to be early Tertiary. Accordingly he tentatively assigns the Wen-ho conglomerate to the Tertiary. It is to be noted that Blackwelder does not mention any progressive increase of angularity, sizes and thickness of the conglomeratic material towards the line of fault, as there would be if the material were derived from the fault scarps. Moreover, the pebbles are fairly well-rounded and water-worn. Thus it appears to be not improbable that the conglomerates owe their preservation rather than generation to the normal faults, or in other words they were formed before the faulting took place. However, the writer has no further evidence to support this view; and he accepts Willis' determination of age of the Wen-ho conglomerate in preference to his own suggestion.

(c) The Gobi series.

The Gobi series of Obrutchov or the Han-hai series of Richthofen is widely distributed in Southern Mongolia and in the neighbourhood of the upper Hwang-ho Valley. The lower part of the series generally consists of clay shales, clays and marls with beds of gypsum and rock salt. The upper part of it is usually a conglomeratic sandstone which often merges into the overlying loess without any sharp demarcation of bedding. At the Zsin-pin-daban, (altitude 4220 m) in the Richthofen mountain, Obrutchov observed red sandstone belonging to the Gobi series overlying rocks which are older than the productus semireticulatus limestone[19]; and he also observed the same series lying in the synclinal valley of Bei-yan-kou.

Fragments of teeth and jaws of mammals were found in a soft marl belonging to the Gobi series at a place between Urga and Kalgan.[22] According to Suess[291] they are undoubtedly parts of Rhinoceros and hence he concludes that the Gobi series belongs to the uppermost stage of the middle Tertiary.

(d) The Coal bearing series.

In Eastern Yun-nan, lignite bearing marls and sands with occasional layers of marly limestone occur in the basins of Lin-ngan, Tang-tche, Sin-hiu, Mien-tien, Mi-leu, Mong-tze. In association with the lignite seams, remains of Tertiary plants occur. In the impure limestone Deprat found Paludines, Planorbes, etc. Deprat assigns this coal bearing series to the upper pliocene. This series is overlain by gravels, sands and marls of alluvial type, & sometimes by Loess.[18]

(e) The Hwang-tu or "Loess".[25,251]

In northern China, large areas are covered by a peculiar formation to which Willis gives the name Hwang-tu or Yellow earth.[236] The term owes its origin to the name of a village, Hwang-tu-chai, Shan-si, Richthofen,[220] Kingsmill[208,209] and others[233] long ago recognised this formation bearing strong resemblance to the loess in the Rhine province of Germany. Hence they call it the Chinese loess. After carefully examining the character of the Chinese loess Willis found that the term loess as is generally understood and as defined by Richthofen does not embrace all the properties of the vast superficial deposit in northern China. Hence he uses the term Hwang-tu in preference to loess.

Apart from recent Alluvium, the Hwang-tu is the youngest deposit of all in China. The processes of its formation are still operating today. As a whole, the Hwang-tu is a soft homogeneous cleyey material which is so fine in texture that it readily fills up the pores of the skin when rubbed. It is usually yellowish gray, but sometimes decidedly blue. Although the softness of the Hwang-tu is notable, large blocks of it often breaks off from the main mass showing irregular fracture.

The Hwang-tu sometimes shows well-defined stratification or even interstratified with gravels and sands, but in most cases, stratification is either obscure or absent. The internal structure of the Hwang-tu is singularly vertical. Tubes having a diameter varying from a fraction of a millimeter to the size of a large organ pipe traverse vertically in a rude parallelism. Calcareous nodules are often found to arrange themselves in a vertical manner, i.e. with their longest axes pointing upwards and downwards. Their presence is clearly due to the effect of percolating water.

From the fact that the Hwang-tu rests on an irregular floor, we can readily imagine that the thickness of it is very variable. In the deepest basin, it attains a total thickness of no less than 1000 ft; toward its margin where it laps over the flank of a hill, it thins out to nothing.

The Hwang-tu is largely distributed in the intermontane valley, but sometimes it occurs on the windward side of local heights and sometimes caps the summit of lofty mountains such as the peaks of the Nan-tai. The surface of the Hwang-tu formation in the valleys is generally concave mimicking the shape of the floor on which it rests, but with larger radius of carvature. This feature is curious and characteristic, affording an unmistakable sign of its presence to a distant observer. Such a feature may be partially explained by its mode of deposition. The wind that carries dust particles is subjected to deviation and disturbance by projecting heights which sometimes cause eddy current and sometime deprive a part of its kinetic energy resulting in the deposition of the load which it carries; since the particles are very fine, they are adherent to any solid body so long as it is not exposed to the sweeping of a strong air current. Under these conditions the loose material would naturally find their resting places on the foot of high mountains, and follow the slope down to the valley. The curvature of the surface thus formed is apt to be exaggerated through subsequent drying and consolidation of the whole body of the Hwang-tu. Imagining in this way, it seems to be probable that the Hwang-tu is a wind-borne deposit. On the other hand the stratification of the Hwang-tu seems to suggest that they may have been formed as sediment in water; in this case the curious concave surface can still be explained by applying the ingenious explanation suggested by Prof. W.S.Boulton to account for the "Symon fault" in Britain.[200] Taking both cases into consideration, the writer concludes that the Hwang-tu was proably transported by wind, and largely deposited on dry land, but in places it may have been formed in water.

Land shells such as pliocathaica, pup (pupilla), Succinea, (Lucena), Metodontia, Bythinia, etc. are frequently present in the Hwang-tu; fossilized birds eggs[165] have been occasionally discovered in it; mammalian remains are now and then reported to occur; but the discovery of the tools used by palaeolithic and neolithic men has not been recorded as far as the writer's knowledge goes.

The imperfect organic remains found in the Hwang-tu do not tell us the exact date from which the formation of this aeolian deposit began. Attributing the change of climatic conditions in Central Asia to the end of the pliocene epoch, Willis assigns the beginning of the formation of the Hwang-tu to the beginning of the Pleistocene time or the end of the pliocene time. Recently V.K.Ting has reported that, in places the Hwang-tu is intruded by dolerite;[198] near the contact between the igneous intrusion and the Hwang-tu, the latter is baked hard, showing that either the formation of the Hwang-tu is an earlier process than it is generally believed to be, or igneous activity has taken place in recent geological time in northern China.

CHAPTER V

IGNEOUS ROCKS IN CHINA

Our knowledge about the igneous rocks in China is still more incomplete than that concerning the sedimentary groups. What has been gathered by the writer from various sources is tabulated below:-

N. E. CHINA

Localities	Nature of the rocks & their modes of occurrence	Remarks
Near Kalgan Chi-li	Trachytic and Rhyolitic lava	Believed to be of Tertiary age. 221
Southeastern Mongolia, north of Shan-si & north of Chi-li	Basaltic and doleritic lava often shows flow structure. Amphibolites also occur.	221 This thick sheet of basic lava covers an enormous area and appears to thin out towards the west; probably of ~~Richthofen speaks of its~~ Tertiary age. (Miocene?)

Round the city of Cheng-te or Jehol, northern Chi-li.	Melaphyre, dolerite, & dioritic rocks occur in association with granite,	235
From the north of Cheng-te to the loess plain, S.W. of Chih-feng latitude 42 20 N. Chi-li.	Quartz porphyry, orthopyre porphyrite with occasional granite occur in large masses and dykes.	235
From Pa-kou about latitude 4I N. to the north of Weng-su-ti about latitude 42 40 N., Chi-li.	Trachytes and andesites occur in association with granite.	235
From Ching-hwang-tau to I-chou all along the western coast of the gulf of Liau-tung, Chi-li.	Granite & other acid rocks	64 The trend of these two igneous zones is approximately parallel to the Sinian trend, viz., N.E.-S.W. The quartz porphyry appears to be the product of fissure eruption. Coal bearing series of ?perm-carboniferous age are disturbed by the extrusion of this porphyry.
Co-extensive with the granite zone but lies further inland, Chi-li.	Chiefly quartz porphyry, occurs in a long belt.	

Liau-si districts, Chi-li.	Numerous sills and dykes of Rhyolitic, basaltic, porphyritic nature.	64 The productive measures of the Nan-pias, Ping-kow, Chou-yang and Pei-pias coal fields are disturbed by the sills and dykes.
In the neighbourhood of Peking, Chi-li.	Diorite and rhyolite-porphyry and small masses of granite.	213 Jurassic?
Nan-kou pass north of Peking, Chi-li.	Granite porphyry andesites and basalts.	231
N.W. of Pao-ting-fu, Chi-li.	Granite occurs in a long belt.	231 The trend of the belt appears to agree with the Sinian trend.
In the mountains near Tang-hsien, Chi-li.	Dykes of gray biotite granite-porphyry with apophysis of aplite.	222 Intruded into the fundamental complex.

Fou-ping-hsien, Chi-li.	Associated with granite is Felspar-porphyry with crystals of quartz.	222 Intruded into the fundamental complex.
From Tang-hsien to Fou-ping-hsien and from Fou-ping-hsien to Wu-tai-shan, Chi-li.	Numerous dykes of dioritic rocks, hornblende porphyries, greenstones in considerable size.	222 They are intruded into the fundamental complex. Some of them are schistosi, others are unaltered They become more abundant from Fou-ping-hsien to Wu-tai-shan.
Lo-toh-liang and Shuang-miao, Chi-li.	Quartz-keratophyre.	207
N.W. of Wan-hsien, Chi-li.	A few small dykes of white aplite & fine-grained granite.	237 Intruded into the Ta-yang limestone. Along the contact with the dykes, the limestone is amphibolized
A little more than a mile S.E. of the village of Wu-tai-shan, Shan-si.	Gneissoid granite.	238 The granite lies in contact with chlorite-schist The latter is cut across by dykes and veins of acid. Granite & pegmatite

Between Shi-tsui & Wu-tai-shan along the Tai-shan-ho, Shan-si.	Numerous dykes of schistose amphibolites or greenstone of fine texture.	The dykes are 20 to 100ft thick and penetrate the fundamental complex, and the Wu-tai schists.
About four miles or more N.W. of Shi-tsui, near Shan-si.	Numerous small dykes of quartz-porphyry. Hornblende-porphyry also occur.	240 Unaltered, Tertiary?
S.E. of Liu-yuan, near Wu-tai-shan, Shan-si.	Greenish hornblende-porphyry and greenstone partly schistose.	241 Intruded into the gray slates of the Hu-to series.
In the Ho-shan range, Central Shan-si.	Granite & other igneous rocks.	242 Associated with the gneisses and schists.
Tai-shan district, western Shan-tung.	Large botholitic masses of medium-grained red granite composed largely of orthoclase, quartz & biotite. Hornblende is usually absent. Some varieties show gray colour owing to the lack of pink felspar & the presence of unusual amount of epidotes & chlorites. Off-shoots of vein quartz & pegmatite radiate from the central granitic	243 The dykes and veins emanated from the central granitic masses cut across schists & gneisses of the Tai-shan complex showing that the granite are intrusions into the fundamental complex. They are probably of Algonkian age. The alter basaltic dykes are belie to be of post Cambrian age on account of their resemblance to those which penetrate Sinisian strata.

	boss. Macroscopically, the granite seldom exhibits gneissic structure; But microscopic examination detects severe deformation.	
In the east base of Man-to butte, Chang-hia, western Shan-tung.	A dyke of greenstone traverses the red granite. Hornblende-syenite-porphyry and syenitic lava are known.	244 The greenstone dyke is cut off at the unconformity beneath the Cambrian shale, showing its pre-Cambrian age.
Kau-kia-pu, S.W. of Yen-chuang, western Shan-tung.	Basaltic and porphyoitic sills.	245 Intruded into the lower and middle Sinisian stra Penno-carboniferous?
I.5mile east of Kau-kia-pu, western Shan-tung.	Laccolitic intrusion with phenocrysts of Alkali felspar & hornblende in a matrix of quartz & felspar.	246 Near the contact of the brown shale with the laccolith cleavage plain are developed in the shale.
In the alluvial plain north of Tsi-nan-fu, western Shan-tung.	Hypersthene-gabbro or norite with olivine.	247 Forming round hills which suggest the shape of remonants of old volcanic necks.

2.5 miles W. S. W. of the city of Tsi-nan-fu, western Shan-tung.	Quartzose syenite-porphyry occurs as a dyke.	248 Intruded into the limestone formation of Tsi-nan-fu.
Yen-chuang coal field, near Sin-tai, western Shan-tung.	Abundant volcanic rocks occurring in the forms of dykes, sills, surface flows, and tuffs. The lava is usually of basaltic habit. The sills and dykes not only consist of olivine-basalt but hornblende-syenite-porphyry and felspar-porphyry. Most of the intrusions are relatively thin.	249 The basaltic flows and tuffs are intercalated with yellow shales and sandstones overlying the productive measure. These igneous rocks are regarded by Richthofen as permian formation.
From Po-shan northward to Chou-tsun, western Shan-tung.	Tuffs and basaltic flows.	249 Intercalated with the red sandstone of the Sin-tai series.
Yang-shan, west of Wei-hsien, western Shan-tung.	Nepheline basalt and other volcanic rocks.	214
Near Tong-tschou-fu, eastern Shan-tung.	Large areas of granite, associated with which are porphyritic rocks. Dykes of dioritic cut across the crystalline limestone strata; sheets of basaltic lava form	223

	an extensive cover of all the bedded rocks in the district.	

N.W. CHINA

Localities	Nature of the rocks & their modes of occurence	Remarks
On the northern flank of the Chi-lien-shan or the Richthofen Mountain.	Large granitic mass.	Intruded into & infolded with the Nan-shan sandstone of Loczy. 215
Near Ku-ku-nor.	Gneiss, muscorrite-granite, granitite, hornblende-granitite and quartz-porphyry are common as well as extrusive rhyolite & tuff gabbro and norite are less common.	25

Tung-lo-pu, Ping-fan-hsien, Kan-su.	Diabase or dolerite.	25
Wu-so-ling, Ping-fan-hsien, Kan-su.	Quartz-diorite and diabase.	

CENTRAL CHINA

Localities	Nature of the rocks & their modes of occurrence	Remarks
Sung-shan, Siung-shan and Fu-niu-shan, Ho-nan.	Large granitic mass.	224 Occurring in association with gneiss and schists.
Between Lio-yang-hsien & Tsau-tien in the western Tsing-ling, Shen-si.	Large bodies of diorite.	Intruded into gneiss schists and crystalline limestone.

Jam-pa-quan, in the western Tsing-ling, Shen-si.	A broad zone of granite.	216
Between Pau-ki-hsien & Tui-tsze-shan in the western Tsing-ling, Shen-si.	A large mass of granitoid rock.	225 Occurring in association with gneiss.
Near Liu-pa-ting in western Tsing-ling, Shen-si.	Granite containing red orthoclase, white plrgioclase, quartz and black mincx sometimes medium-grained & sometimes course-grained. Dykes of granite, & veins of quartz and pegmatite are given off from the central mass.	226 The dykes and veins cut across "Silurian" limestone. This granite is less strained than the northern granitic mass of the western Tsing-ling exposed to the north of the Tui-tsze-shan.
South of Lan-tien-hsien, Shen-si.	Granite.	25
In the Han-kiang district, south of Shen-si.	Granite and gabbroid rocks occur. Dykes of poikilitic saussurite-gabbro are common.	213 "They are probably post Triassic in age".

In the neighbourhood of Siau-ho, eastern Tsing-ling-shan, S. Ho-nan.	Large masses of diorite.	In association of biotite schists.
The main range of the eastern Tsing-ling, Ho-nan.	Large granitic mass no signs of deformation have been detected.	This granite petrologically resembles the Fu-niu-shan granite.
The northside of the Tsing-ling pass, Shan-si.	Black & white granite of uniform and medium grain. It is composed of glossy quartz, microcline orthoclase, biotite, hornblende, sphene, apatite epidote.	Granite frequently occur in the central Tsing-ling. According to Bailey Willis the lithological type of the varieties is exemplified by a specimen from the north side of the Tsing-ling pass and that from the vicinity of the Si-ting-ho. The former type of granite prevails in the central and northern portions of the Tsing-ling-shan.
On the southern side of the Tsing-ling pass, Shen-si.	Massive granite of clear-gray colour; it is not traversed by dykes except veins of pegmatite & aplite.	

Near Shi-ting-ho, Shen-si.	Pale reddish granite of porphyritic texture. with phenocrysts of twined orthoclase of the carlsbad type & a fine matrix of orthoclase & quartz and some ferromagnesion constituents. Gneissoid structure is noticeable in some of the exposures.	Between Liu-yue-ho and Ir-ling-pu, the granite lies in contact with the Hei-shiu series (limestone). The latter shows the effect of contact metamorphism. Willis regards his Hei-shui serie as carboniferous formation, and accordingly he regards the age of the granite in the Tsing-ling shan as probably being post-carboniferous.
In the gorge district of the middle Yang-tze. Above I-chang, Hupeh.	Gneissoid granite or quartz diorite. Consisting of quartz, plagioclase, biotite, hornblende, epidote and magnetite.	219 Pumpelly observed that the texture of the igneous mass becomes fine and the ferromagnesian minerals become more abundant towards its margin. This fact seems to indicate the effect of magmatic differentiction and therefore tends to prove the intrusive nature of the granite. Willis regards it as an intrusion of Algonkian and possibly late Algokian age.
The hill range of the Pei-yang-shan, Hwang-gang-hsien, Hupeh.	Greenstones and other igneous masses.	Muscovite and biotite are abundantly developed along the contact between the country rock and the intrusion.

San-hu-shan, near Hwang-shi-gang, S.E. Hupeh.	Porphyry rich in quartz with highly weathered large crystals of orthoclase.	227 Intercalated with the productive measures of upper carboniferous or permian age.
Ta-ye-hsien district, S.E. Hupeh.	Granites & syenites occur in the form of bosses of moderate size.	48, 49 The limestones in contact with the igneous masses show the effect of metamorphism. Large bodies of ore deposits have been derived from these igneous masses either thr through the process of differentiation from the original magma or metasomatic changes on the part of the limestone.
Kiu-gong-shan on the divide between S.E. Hupeh & N.W. Kiang-si.	48, 49 Granite.	
Hwen-gang-shan, Do-yun-shan etc. from Kwang-ji-hsien and Hwang-mei-hsien, S.E. Hupeh.	Gneissoid granite & granite porphyry with occasional (diorite?)	252 Occur in association with gneiss and schists.

WESTERN CHINA

Localities	Nature of the rocks & their modes of occurrence	Remarks
O-mei-shan, O-mei-hsien, western Su-chuan.	Granite. 232	These granitic masses appear to be genetically connected. They are distributed in a long belt extending in the meridional sense. In the Lo-lc district Legendre observed that the porphy is sometimes overlain by the plateau-forming limestone (Triassic?) in the Lo-lc district.
Near Tien-chuan and Ya-chou, western Su-chou.	Granite. 211	
From Ning-yuan-fu to Tse-ta-ti and Ta-pac-shan, S.W. Su-chuan.	Granite and porphyries.	
Chen-te, Su-chuan.	Granite, hornblende-granite, quartz-diorite, diabase-porphyry, course-grained gabbro.	213 Associated with gneiss and schists.
Tz-de, Su-chuan.	Fine-grained gabbro.	213

Dcha-ra-la pass, Su-chuan.	Quartz-andesite.	213

S.W. CHINA

Localities	Nature of the rocks & their modes of occurrence.	Remarks
Between Ya-long-kiang and Kien-chwan eastern Hui-li-chou, northern Yun-nan.	Quartz-leptymite cut by large dykes of nepheline-syenite composed of Alkali felspars, nepheline, sodalite and cancrimite, with aegirite and subordinate amount of arfvedsonite, lepidomelane and sphene.	213
Kan-lang-chai, Yun-nan.	Muscovite-biotite-granite and augite andesite with phenocrysts of labradorite and in some varieties hornblende.	213

Ho-chuen-shan Sze-chen-yi, Yun-nan.	Felspar basalt with some hornblende-andesite at the summit.	Extinct volcano. 213
N.E. Yun-nan.	Bedded lava of labradorie melaphyre containing large crystals of olivine, augite labradorite etc.	An extensive formation intercalated with middle carboniferous rocks. 218
Near Mei-tchai, on the rivers of Kou-tchou eastern Yun-nan, and in the zone of Hou-kouang fracture.	Andesitic porphyrite showing microlitic structure with microlites of olijoclase, augite andesine and a vitreous matrix. Sundary chlorite and sphene are also present.	
Between Tie-tchen-ho and the fault of Tchou-yuen, S.E. Yun-nan; Fong-wou-shan, west of Siun-tien-tcheou, N.E. Yun-nan.	Balsaltic lava and tuffs with "labradorite" and "cinerite".	Capping the upper permian formation. This permian volcanic series is exposed in a large number of localities in eastern Yun-nan. 15

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In the districts of the Red River and the basin of the Mong-tseu & the base of Nan-ti, S.E. Yun-nan.	Granites, leptynites, or tourmaliniferous pegmatite, with amphibolites and gabbro.	These occur in association with gneiss, schist and granular chlorite-marble (cipolin). The staniferous deposits in S.E. Yun-nan are derived from these igneous masses. The metamorphisim in these regions is intense: In some cases, the metamorphosed group occurs in contact with the unaltered upper carboniferous (Ko-kcu) but in other cases the metamorphisim even affects the Triss. (Ko-tieou) At Nan-ti, the whole of the palaeozoic group, including the Upper Carboniferous, is involved in the metamorphism. Deprat states that the granite probably arrived sometime during the Devonian-Rheatic period and probably more than once.
S.E. of the lake Ta-li, N.W. Yun-nan.	Porphyry.	
In the vicinity of Ping-tchou, N.E. of Nan-ning, Kwang-si.	Large granitic boss. Veins of quartzose tourmalinite cut across the granite.	
Kwang-chou-wan S.W. Kwang-tung.	Basalt.	213

Ko-tio, S.W. Kwang-tung.	Gabbro or bytownite-diorite grading into amphibolite; Tourmaline pegmatite and melaphyres also occur.	218
The isle of Hainan, Kwang-tung½	Granite occurs in southern part of the island; tuffs and lavas are found in the northern part of it.	63

SOUTHERN & S.E. CHINA.

N.E. of Ho-hsien & west of Lien-shan-hsien, on the divide between Kwang-tung & Kwang-si.	Massive granite occupying large area.	253 In the neighbourhood of the granite tin ores occur. Signs of disturbance are recorded in the sandstone, shales and quartzite surrounding the granite.

Near Shi-liang N.W. of Hwai-tzi-hsien, Kwang-tung.	Granite.	253 Appears to be genetically connected with the granite occurring near Ho-hsien.
In the vicinity of Kwang-ning-hsien, Kwang-tung.	Biotite-granite often exhibits "porphyritic structure".	253 Associated with granitoid gneiss and micaceous schists.
North of Canton, Kwang-tung.	Granite traversed by quartz veins and occurs in blocks. The size of the blocks range from a few feet to a few hundred feet.	210 The granite is deeply weathered. Large & small blocks lie at random on the residual red soil resulting from the decomposition of the granite. These pseudo-boulders have entertained the erroneous idea of glacial action.
In the vicinity of Hong-kong, Kwang-tung.	Quartz-porphyry with breccias & tuffs. Biotite-granite & granite-porphyry, quartz-porphyry also occur. In some cases the granite-porphyry shows flow structure.	These granites probably arrived at the same geological time.

Between Lien-kiang-kou and Hwang-shi, Kwang-tung.	Course-grained biotite-granite.	254 The "palaeozoic" slates, sandstones, limestones etc. show the effect of contact metamorphism round the granitic masse
North of Hwei-chou, Kwang-tung.	Biotite-granite Probably continuous with that exposed to the north of Canton.	
Bei-ma-miau, Lung-nan-hsien, N.E. Kwang-tung.	Biotite-granite.	
Tong-shan on the divide between Kiang-si and Kwang-tung.	Biotite-granite.	
Hu-nan.	A large number of granitic intrusions.	The ore deposits in the province of Hu-nan are due to these intrusions.
Hwei-chang-hsien, Dja-kiang-hsien, and Ta-hu-chien, Kiang-si.	"Porphyritic" biotite-granite.	254 Intruded into the "palaeozoic group".
South of Lu-shan, northern Kiang-si.	Granite.	32

Su-shi-li-pu between Tung-chien-hsien & An-king, northern An-hwei.	Granite.	32
Hong-chia-chau, N.W. of An-king, northern An-hwei.	Biotite-granite often occur as sills.	252 Injected into "palaeozoic limestones and slates.
In the districts of Chin-yang-hsien, Tai-ping-hsien and Hwang-shan, southern An-hwei.	Granite.	32
Northern Kiang-su.	Basaltic and andesite lava.	232 Exposed in patches protruding from the mantle of loess.
Wu-tshou-shan, Kin-shan etc. near Tshon-kiang, Kiang-su.	Hornblende-granite or tonalite.	228 At the Kin-shan the granite has intruded into a flinty and dolomitic limestone.
Hsiang-shan, near Tshou-kiang, Kiang-su.	Porphyries.	229 Associated with altered sandstone, marble and quartzite.

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On the top of the Mei-hwa-shan, near Nan-king, Kiang-su.	A patch of doleritic rock.	The rock is largely covered by loess. Richthofen thinks that it is probably a volcanic neck
Eastern Che-kiang.	Quartz-porphyry with subordinate amount of granite occupying a large areas.	Associated with tuffs and agglomerate. The quartz-porphyry often penetrates the granite.
In the district of Gwang-tzei-hsien, on the divide between Kiang-si and Fu-kien.	Massive granite.	These igneous rocks are sometimes exposed between belts of "palaeozo sandstone, slates, and limestone with coal seams and sometimes between shales and sandstone of doubtful mesozoic age. The granitic and porphyritic zones appear to assume a N.N.E.-S.S.W. extension, i.e., parallel to the coast line of Fu-kien.
From Shau-wu to Yen-ping-hsien, Fu-kien.	Granite with quartz-porphyries occupy large areas.	
In the district of Dji-chie-hsien, Fu-kien.	Granite.	
	212	
From Ku-tien-hsien to Fu-chou, Fu-kien.	Riebeckite-granite and quartz-porphyry. Diabase occurs to the west of the granitic zone.	

In the mountains south of Tchang-ping-hsien and N.W. of Amoi, Fu-kien.	Granite.	
Near Amoi, Fu-kien.	Granite associated with "gneiss and schists".	
In the mountains of Nan-an, Tung-an, An-ki, Chen-chou etc., Fu-kien.	Quartz-porphyry, biotite-granite with other basic igneous rocks.	
All along the S.E. coast of China, from Che-kiang to Kwang-tung, and in the adjacent islands.	Volcanic activity made a grand display by ejecting an enormous quantity of porphyries, quartz-porphyries, quartz-felsite, granite volcanic conglormerate and breccia. The rocks are as a rule of acid or acid-intermediate character, but dykes and laccoliths of basalt and other green rocks are also found, penetrating the more acid masses.	234

CHAPTER VI

GENERAL GEOLOGICAL STRUCTURE of China.

The study of geological structure, or tectonics, as Prof C, Lapworth has already pointed out, implies the study of the present surface feature (epidography), the succession of strata (stratigraphy), and the recognizable or inferred deformations (Geo-eidography). The first and the second have already been dealt with to some extent. At present it is intended to gather observed facts which appear to throw light upon the principal features of deformation and dislocation of Chinese Strata, and as far as the available information permits, to infer the date at which, or the period during which such deformation or dislocation took place. In a broad way we may divide eidographical features into three classes: (a) folds, (b) faults, (c) thrusts. Not only the classes (b) and (c) merge into each other by all gradations, but along one and the same line of disturbance we may find both folding and faulting. Abundance of such examples is found in China.

Since the surface features of a Country are controlled to a large extent, either directly or indirectly, by its eidographical structure, it is natural to connect our study of tectonics with the study of physiography. This principle is persistently observed in arranging the present chapter.

(The reader is recommended to read the summary (p 333 to 334) first on the understanding that it is largely inferential; and ~~also he is requested~~ to compare the tectonic description of the several regions with plate I).

Eastern and Southern border of the Mongolian plateau.

The Khingan flexure We have already seen that the Mongolian plateau is bordered on the east by a mighty range of the Great Khingan. (see p 22). This range only possesses an eastern slope. The northern portion of it consists of a very broad fold in which the Angara beds in the plain of Amur and those in the Gobi region to the west of the great range are involved. Rhyolite and basalt occur on both sides of the folds. The eastern side of the range is sometimes steep and even precipitous. Suess raises the question whether this range is a "true flexure" produced by subsidence or a line of simple folding. He deals with this question at some length,[144] by comparing a variety of opinions, finally he finds himself in favour of a "flexure" as defined by Heim, i.e. a monoclinal fold accompanied by faults with downthrow to the east. Richthofen taking advantage of the fact that the trend of the great Khingan is similar to that of the faults and flexures which form the eastern border of the Shan-si plateau, indicates on his map a hypothetical, continuous ~~flexure~~ line at a distance passing the eastern flank of the great Khingan and the eastern edge of the Shan-si plateau.[27] The writer is unable to find any positive evidence given by Richthofen to show that these two flexures are really genetically connected as they appear to be from his map.

The age of the Khingan flexure   Since the Angara beds are involved in the folds of the northern Khingan, it is evident that the folding and faulting which produce this long monoclinal flexure, took place in post Jurassic time. From the simple and similar structure all along its length, we may infer that it has been probably formed by a single process of earth movement — a bodily sinking of eastern Asia or at least Manchuria. Elsewhere in Asia such gigantic movements during post Jurassic time are only known to have occurred in the middle Tertiary and the beginning of the pleistocene. Assuming there has been no other earth movement of great magnitude between Manchuria and Mongolia after the formation of the Angara beds, it follows that either Mid-Tertiary or post-Tertiary movement must have been responsible for the building of the great Khingan. If one is allowed to judge by the available data which are far from being adequate, one would be inclined to connect the fissure eruption consequent to the Khingan movement (see the previous page) with the extensive volcanic flow in the neighbourhood of Kalgan, Southern Mongolia, during and after ? Miocene time. (see p 247)

The flexures of the Southern border of the Mongolian plateau.

About half way between Tutinza and Hanoor, forming the divide between N.W.Chi-li and S.E.Mongolia, a plateau rises to a height 5,400 ft above the sea level. According to Pumpelly,[76] the precipitous wall of the plateau faces ~~towards~~ the south, but on the northern side of the edge of the plateau a gentle slope follows northward. The wall extends towards the west and northwest. To the south of the wall there are to be seen rugged mountain with rivers winding in the valleys. To the north of it a vast plain strewn with a few low hills extends beyond sight. The surface of the plateau near its edge is dissected and sometimes incised to a depth of several hundred feet. The tops of the dissected heights lie in the same plane indicating that they were originally continuous. The width of the valleys between the heights varies from several hundred feet to three or four miles. There are streams winding through them. From the base to the top of the wall nothing but volcanic rocks are found. It is believed by Pumpelly that the plateau is largely if not entirely, formed by volcanic rocks. Towards the west the plateau is succeeded by another plateau of similar type. Further west a broad swell or ridge makes its appearance. The extensive and thick sheat of lava thins towards the west.

The age of the southern Mongolian flexure. From the facts stated above the writer infers that a mighty normal fault succeeded towards the west by an unbroken flexure ~~must have~~

probably occur along the northern border of the provinces of Chi-li and Shan-si. The faulting and folding must have taken place in relatively recent geological time for the fault cuts the Tertiary lava off on the south.

The western part of the In-shan range which borders the north of the rectangular Shen-Kan plateau, has been described as a sharply defined block. (p 24). The wall-like edge of this range strongly suggests a fault plane being eroded to some degree. This hypothetical fault may prove to be continuous with the southern Mongolian flexure.

THE GRILL OF PEKING.

On Richthofen's map we note that the area embracing the parallel mountain rangers in N.W.Chi-li is largely occupied by three different geological formations: The oldest group of gneiss and schists generally crops out on the lower part of both flanks of each ridge, the upper part of the ridge being covered by the younger group "Sinisch". In the valley we find the youngest group loess. If Richthofen's observation is correct our natural interpretation of the structure of the "Grill" would be to regard it as parallel synclinal hills with their axes running N.E.* This simple but singular structure appears to extend over a considerable area. North-Eastward the Grill passes Cheng-te-fu and reaches Eastern Mongolia. Northward it gradually sinks below the platform

* Strikes described as E.N.E by some writers.

of recent lava; in the vast lava field the parallel ridges are however sometimes left unburied.[145] Southwestward a structural change pakes place on the eastern border of the Hin-chou basin.

According to Richthofen the northeastern prolongation of these parallel structural lines encounter a bend near Kai-ping, i.e., the trend changes from N.E. to N.N.E. and continues to run in a N.N.E. direction on the western side of the valley of Mukden. Making use of this suggestion, Suess says; "If this should prove to be the case - - - - there would be a transition to the direction of Khingan"[146] which runs N by E. This view is confirmed by the observations made by Fritsche[23] who travelled from Peking towards the north. After crossing the watershed between the Lan-ho and the Liau-ho, Fritsche reached parallel chains trending N.N.E. He remarks that from Kalgan to Fon-niu-hsien the ranges bend from N.E. to N.N.E. and finally unite with the southernmost part of the Great Khingan, thence they assume the N N E trend. From the fact that the orographic axes generally agree with the tectonic axes in this part of the country, we may safely infer that the bending of the trend of the ranges also represents the bending of the general strike of the folds.

In the Wang-ping coal field, west of Peking, two systems of folding have been recognized by N.F.Drake. One strikes E-W, the other strikes S.W. The latter agrees with the prevailing trend of the parallel hill ranges further northeast, and apparently they are genetically connected. The E-W folds play an important rôle in the western and central part of the coal field, the Chin-lung-shan and the Ching-shui-shan synclines are examples of this system. The southern anticline accompanying these synclines extends westward from the eastern end of the Ma-an-shan, and the accompanying northern anticline extends westward from near Hao-chia-fan. They bring up the Sinisian limestone to the surface, and flatten or die out towards the plain of Peking where the beds lie in the syncline of the N E- S W fold. To the S.W. of Pao-ting-fu the N.E.-S.W. folds are again the principal structural feature. In the same district the massive limestone underlying the coal bearing series, stands out in relief on both sides of the soft productive measures. Throughout the districts of Ling-shan, Mi-chang etc, S.W.Chi-li, the coal bearing series owe their preservation to the prevailing N.E.-S.W. folds.

Dates of the deformations ~~Regarding the reported.~~

Regarding the reported occurrence of conglomerate at the base of the "coal measures" near Peking as a sign of vigorous erosion resulting from the prevailing N.E.- S.W. folding, Pumpelly writes:[77] "The Sinian revolution (the N E - S W folding) seems to have begun after the deposition of the limestone, (presumably he means the Sinisian limestone) and before that of the coal measures" Judging from this statement Pumpelly apparently did not observe or neglected the important fact that the so-called coal measures are also involved in the N.E.-S.W. folds. With regard to the "Grill" Suess vaguely remarks[147] that it dates from a very early period. His inference is based upon the fact that, in the parallel ranges, the Cambrian beds lie almost flat upon the gentle undulation of the ancient gneiss mountains. Neither of these views can be regarded as satisfactory.

Since the coal bearing series is affected to the same extent as the underlying limestone by the N.E. folds, it is almost certain that the N.E. folds traversing the coal fields of western Chi-li; and their probable northeastern continuation that produce the "Grill of Peking", came into existence not earlier than the end of the period during which the coal bearing series was deposited. Further discussion ~~with regard to~~ on the precise age of the prevailing N.E.-S.W. folding in China cannot be conveniently attempted until we have made a broad survey of the general structure of the whole country. (see p 331) With regard to the E-W folds, the available data do not enable the writer to deduce their age.

The Principal Tectonic Features of Southern Manchuria.

The structure of Southern Manchuria is closely related to that of the northeastern provinces of China proper. The discussion of the latter naturally touches upon the former. Therefore it is necessary to indicate the essential tectonic features in this chapter, though it is outside the scope of this thesis. The principal geological formations of southern Manchuria are (a) Gneiss and Schists including Corean Granite (b) Sinisian formation (c) coal bearing series (d) Sandstone group (e) Tertiary formation with coal seams. The lowest group, i.e, the gneiss and schists together with the Corean Granite, is everywhere in South Manchuria impressed by two sets of strikes.

perpendicular to each other: The E N E - W S W set appears to be ~~given~~ genetically connected with the W N W - S E S set.

E.Cholnoky[3] has described the essential tectonic features under four groups: (a) The road from Mukden to Kirin runs along the northwestern part of the Kuleh mountain or the Kulek plateau. Almost coinciding with this road, a line of great fracture extends in a N E - S W direction, separating the S.E. Liau-tung peninsula from the Liau-ho valley. All along this line young volcanic outpourings of the fissure-eruption type occur in great masses. This line cuts obliquely across the prevailing E N E ~~W S W~~, and ~~W N W~~ - S S E structural directions of the ancient gneiss and schists. (b) The parallel mountain ranges issuing from N.W. Chi-li are cut off by a fracture in Liau-si running along the western border of the Liau-ho valley. These two faults, (a) and (b), meet in the vicinity of Kirin according to Cholnoky who draws his inference from the great development of volcanic masses in that district. Being bounded on the N.W. and S.E. by these two faults the valley of the Liau-ho may be regarded as a graben. (c) A third fault runs along the eastern foot of the Chang-pei mountain and follows the course of the river Ya-lu. Southwestward, it appears to bend, until finally meet the prolongation of the Mukden Kirin line at a place in northern Shan-tung, where there is an intense development of volcanic rocks. The disturbance of strata observed along the S.W. corner of Liau-tung peninsula tends to confirm this view. (d) Between the Ya-lu fault and the Mukden-Kirin fault lies the horst of the Liau-tung peninsula. This horst is folded or warped along axes trending E-W:

The Tuh range and its parallel granitic ridges in the north of Liau-tung, and the range of Shang-pai in southern Liau-tung are regarded by Cholnoky as examples of this group of folding. He further remarks that the Little Khingan with its general E-W trend may be referred to the same group.

In the valley of the river Hsi, W.A.Moller[64] observed folded coal bearing series of Tertiary age striking N E - S W. The folds are generally gentle and undulatory; but occasionally, they are as acute as to produce dips varying from 70° to 80°. Wher denudation has gone to an advanced stage, the coal seams crop out at the top of the ridges. But in the majority of cases the lower coal bearing series is covered by the upper barren sandstone. The undulation of the beds follows, to a great extent, the present surface feature of the valley.

The age of the deformations and dislocations   The E N E and the W N W strikes exhibited by the ancient gneiss and schists appear to represent the oldest discernible group of deformation in this region. It has been frequently mentioned by Richthofen and others that the Cambrian strata in the Liau-tung province lie unconformably upon the pre-Cambrian gneiss and schists. The former are clearly not involved in the extreme deformation suffered by the gneissic and schistose group. Therefore the earth movement or movements which impressed the E N E and the N N W strikes on the ancient formations must have taken place in pre-Cambrian time. Subsequent disturbances acting in E N E and N N W directions possibly exaggerated the pre-Cambrian trends. The faults delineated by Cholnoky have played important parts in determining the present relief of southern Manchuria. Hence they are likely to be of recent age. Along the lines of fracture we find masses of young volcanic rocks which are comparable in composition and in type with those found in southern Mongolia and along the Khingan flexure . We have already determined the age of the Khingan flexure to be ? Miocene. Through the link (a weak one)of the similar occurrence of the volcanic rocks we may also tentatively assign ? Miocene age to these faults. Moller's observation in the Hsi-ho valley clearly shows that earth movement must have occurred in the valley either in the later part of the Tertiary period or in post Tertiary time. Judging from the fact that the undulation of the surface of the ground largely follows the anticlines and synclines, it is evident that denudation has not gone on to any extent since the folding had taken place; and therefore the movement was probably a recent event.

Nan-shan ranges and their eastern prolongation.

With regard to the structure of these important ranges, we have at present very few reliable data. The facts that have been made known are briefly indicated as follows:-

According to Obrutchov[69] the trend of the Alexander III range, (see physiography p 28) the Suess mountain, and the valley of the Su-lei-che does not follow the strike of the rocks. Consequently the coal bearing sandstone series of ? Mesozoic age is exposed in a series of troughs between the crests of older rocks on the main chain of the Alexander III range. Along the valley of the Su-lei-che, on the northern flank of the Suess mountain, Obrutchov observed a large syncline formed by a thick series of strata which he calls "post carboniferous series" (see section No.2) following both the northern and southern limb of the syncline are found coal bearing formation to which he assigns carboniferous age. The so-called carboniferous deposits are again unconformably followed (underlain?) on both sides of the large syncline by altered "Devonian" rocks which consist of green and red slates with intercalated limestone layers. On the southern side of the central syncline, the "Devonian" strata themselves are folded in a compressed anticline with its axial plane turned toward the south.

A greater part of the Alexander III range between the valley of the middle Su-lei-tschwan and that of the To-lai-chun is occupied by massive variegated sandstone and shale to which Obrutchov assigns "upper carboniferous age" These "upper carboniferous strata" are sharply folded on the northern flank of the range, but less so on the southern flank of the same range. Strata of pre-carboniferous age are also indicated on Obrutchov's section (see section No4) They occur in a highly compressed manner along the lower part of the northern flank of the Alexander III range.

Along the northern flank of the Richthofen mountain, the northernmost one of the Nan-shan ranges, Obrutchov observed (see section No.3) a granite zone along the lower part of the slope, which is followed upwards by coal bearing series of "carboniferous" age, and the green and red slates with intercalated sandstone of "Devonian" age. These strata dip almost vertically. Travelling toward the top of the main chain of the Richthofen mountain the same author observed compressed strata of ? Mesozoic, and "Silurian" age standing on their ends. In the valley of the Si-ning-ho, near the S.E. termination of the south Ku-ku-nor range, Obrutchov noted an extensive flat sheet of Gobi deposits resting upon the steep "Archean strata" which form the Ku-ku-nor range. The inclination of the "Archean strata" is often as steep as 70° to 80° In the valley of Bei-yein-kou the extensive Gobi-series strikes E-W.

The structure of the Nan-shan ranges is highly complex. Though each range is a morphological unit, it possesses no tectonic independence. Broadly speaking, the folded strata forming the nothern ranges show some tendency of overfolding towards the north, while the rest of the folds appear to point southward. Thrusts and faults are relatively rare as far as we know.

Along the foothills of the southeastern Nan-shan ranges K.Futterer has made the following observations: Between Kan-chou and Lian-chou, the "Jurassic" and "carboniferous" coal measures are exposed at three localities Shan-tan-hsien, Sin-ho-yi and at the south of Hsia-kou-yi. The exposure of coal seams in these localities is probably due to folding. The productive measures are quickly buried by clay and loess towards N.W., E., and S.E. Between Ku-lang-hsien and Chiu-chao-yi the "Quarternary" sandstone strikes E 10 N and dips 55S. To the south

55S. To the south of the Ping-fan-hsien and the north of Thung-yuan-yi, in the neighbourhood of a pass, soft shaly sandstone and conglomeratic strata strike E 15 S dip 23S. On the northern side of the pass the strike of the same strata changes to E 10 N and they dip 60S. The coal bearing series exposed near the valley of the Ta-thung-ho strikes E 20 S dip 15°N. At the north of Ping-Kou-yi and at many places above the Si-ning-ho the "Quaternary formation" of red sandstones and shales strikes E 35 N to E 30 N. Near Ping-tsou-yi, S.E. of Si-ning-fu, and at many localities in the neighbourhood of long. 100° E. latitude 35° 25' N, the "Quaternary formation" strikes E.15 S. and the strata are thrown into wavy folds. In the east of Yei-tien, north of Min-chou, the "Quaternary formation" which consists of marly, sandy,and conglomeratic beds, strike from E 30 S to E 5 S. Between Kiu-tien and Yei-tien, bedded green-grey quartzite striking E 20 to 15S, and two series of limestone strata forming a single hill but differing in dip are exposed.

From these observations and others recorded in Futterer's work "Durch Asien", we gather that, in the neighbourhood of Ku-lang-hsien, northern Kan-su, the strike of the so-called Quarternary strata follows the trend of the eastern prolongation of the Nan-shan ranges, which bends towards east and northeast. (see p 14) From the S.E. of Si-ning-fu towards southern Kan-su, the same "Quaternary strata" strike E 15 to 5 N. Evidently, from the latitude of Si-ning-fu or its neighbourhood towards the south, the axes of the folds of the

"Quaternary strata" agree with the general trend of the mighty Tsing-ling range.

Having gathered a few disconnected facts ~~of importance~~ bearing on the structure of the Nan-shan ranges and their southeastern foothills, we may proceed to note some principal tectonic features of the Ala-shan range standing on the western margin of the Shen-kan plateau. This range terminates on the south in a broad range of moderate height, the Ye-tou-shan, which is traversed on the southern part by fractures running in E-W direction. Obrutchov regards this height as a horst. The strike of the ancient rocks that form the Ala-shan range does not coincide with the trend of the range in a great part of its western portion: The rocks strike N N E while the orographic axis of the range, more or less follows the course of the Hwang-ho, viz. it bends from N N E to E N E as it proceeds northeastward. Deep ravines and canons ~~are~~ cut across the mountain in a direction corresponding to the strike of the rocks but oblique to the orographic axis. It has been already pointed out by Loczy, Suess, Obrutchov, that the ranges bordering the Hwang-ho are in some way related to the southeastern termination of the Nan-shan ranges. To this important suggestion the writer ventures to add the following remark: If we produce the axial lines of the Grill of Peking and the Charanarinula range in southern Mongolia to the S.W. and those of the Nan-shan ranges towards the S.E., we would find them meeting in about longitude 107°E. (nearly the longitude of Pin-liang-fu) Thus we get an imaginary arc formed by produced chains. This arc shows a similar rude parallelism to the amphitheater of Irkutsuk which is believed by Suess to be the innermost one of the concentric arcs characterizing the structure of Eastern Asia.

The dates of the deformations   The available data are insufficient to enable us to deduce the dates of the deformations hence it is not attempted here. We may note however, with certainty, that folding in very recent geological time affecting the so-call Quaternary deposits, has taken place. Suess makes a similar comment.[148]

The Shen-kan block.

The surface of the Shen-kan plateau is largely covered by the Hwang-tu or loess. Only here and there isolated hills composed of ancient limestone or other rocks pierce through the extensive sheets of superficial deposits. Although its structure is hidden, for the greatest part, from sight, we have reason to believe that deformation and dislocation of great magnitude have not taken place in this area since a very early period of geological history. The principal reasons are (1) the surface feature is essentially even. Mountains in the shape of dissected chains are only known in the northwestern corner of Ordos. (2) The general structure of the region lying to the east of it is simple, strata of Cambrian age often lie flat or with a only gentle inclination. We have already inferred that the northern border of the plateau is probably bounded by large normal fault, while the southern limit of the area appears to pass into the zone of intense folding of the Tsing-ling range by relatively insignificant folds. Broadly speaking, the plateau is a rectangular block fractured on its northern end & being thrown down against the Mongolian border, but unbroken on the southern part. It is not surprising if we discover that the western and the earlier limbs of the great bend of the Hwang-ho have taken advantage of two lines of great fracture. The constrained bending of the mountain ranges lying to the north of the Hwang-ho may be looked upon as waves of parallèl folds coming from the N.W. and being arrested or deflected by this stubborn block.

The last statement would incidentally put the date of faulting on the northern border of the Shen-kan plateau previous to that of the folding which has built the ranges (at least some of them) on the southern edge of the Mongolian plateau. However one is hardly justified to do more than to put forward this idea in the absence of further evidence.

S.W.Chi-li and Shan-si.

Valuable accounts of the structure of these regions have been given by Obrutchov, Richthofen, Bailey Willis, Blackwelder, and others. The observations made, and the inferences drawn by Bailey Willis and Blackwelder seem to be particularly important. They spent a great part of their time in these regions during their research in China, and also they had the opportunity to review the early publications contributed by Obrutchov and Richthofen. For these reasons, the following information is largely drawn from the "Research in China" (vol. I part I)

In the Wu-tai district, N.E. Shan-si, Willis and Blackwelder distinguish at least four groups of rocks from structural point of view. They are described below from the oldest to the youngest.

(a) The highly metamorphosed Tai-shan complex exhibits banded structure. The banding and jointing of this ancient group of rocks frequently approaches horizontality, mimicking the stratification of ordinary sedimentary rocks. Sharp contortion in small scale is the principal feature of the Tai-shan complex in this district as in other places where the fundamental group is exposed.

(b) Along the southeastern flank of the Wu-tai-shan, (section) ~~generally~~ rocks of the Wu-tai formation dip towards N.W. at angles generally varying from 70° to 80°, but occasionally as low as 30°. Repetition of beds in the sequence shows the probable existence of thrust planes; and the occurrence of a series of similar beds on both sides of certain strata, in reversed order, etc have led Willis to interprete the structure to be a closed syncline. (see p) He also thinks that the Wu-tai formation occurs along the southeastern flank of the Wu-tai-shan in imbricated or Schuppen structure, "of which the southeastern element, the Shi-tsui series, includes the oldest strata and in which each element towards the northwest takes in higher and higher strata".

(c) In the southwestern Wu-tai district the uppermost series of the pre-Sinisian rocks, the Hu-to series occurs in many minor folds, usually of a somewhat open character. The pitch of these folds is toward the southwest. Willis thinks that these folds lie in a broad synclinorium, and in accordance with this general interpretation of structure he regards the argillaceous group of the Huto rocks exposed towards the northeastern margin of the inferred synclinorium as lower series; and the calcareous group exposed in the central and southwesternpart as the upper series of the Hu-to formation.

(d) The palaeozioc group and the younger formations occurring in the Wu-tai district generally form broad shallow synclines which are barely deep enough to retain small isolated patches of the coal bearing series of ? permo-carboniferous age. (Tien-hua, Yua-tou, Chung-hua) Associated with the synclines are sharp anticlinal folds. They are sometimes so sharp that strata of insignificant thickness are pinched up in the shape of a keel. (S.E. of Shi-pan-kou, E, of Tou-tsun). Overfolding and thrusting suffered by the Ki-chou limestone or Sinisian limestone are also known in the hills of Tou-tsen, in the canon of the Sing-ho, S.E. of Wu-tai-hsien, and elsewhere in the Wu-tai district.

The mountain Ki-chou-shan, southeast of the Hin-chou basin exhibits highly complicated structure. The lower strata of the Sinisian formation stand almost vertical or even overturned in the northern foothills of the mountain. They are repeatedly overthrust from the north, sometimes by the Hu-to rocks and sometimes by the pre-Sinisian granite, and on the southeast are succeeded by overlying limestones, (the Ki-chou limestone) in a sharp compressed syncline. To the southeast of the crest of the mountain,anticlines and synclines involving coal bearing series, probably of permo-carboniferous age, occur. The trend of the flexures is more to the west of south than that of the wall-like front which forms the northwestern edge of Ki-chou-shan. Consequently the outcrops of folded limestone strata arrange themselves en echelon. The wall-like, and slightly convex front of the Ki-chou-shan runs continously for a distance of 20 miles without prominent spurs. Its surface is gashed by ravines, but not yet deeply dissected. The surface of the front sometimes shows parallel grooves, which are taken as slickensides. These features have led Willis to believe that the steep front is a fault-plane. Through this Ki-chou fault the folded and thrusted strata which form the Ki-chou-shan, are cut off abruptly and lifted up at least, 3000 feet above the surface of the Hin-chou basin. Southwestward, the Ki-chou range extends beyond Shi-ling, thence it sinks beneath the Hwang-tu plain.

~~Broadly speaking~~ in general the deformed Sinisian strata which form the greatest part of the Ki-chou range, lie on the southeastern side of a belt of pre-Sinisian formation. The latter is regarded by Willis as a large anticlinorium covering the area of the Wu-tai district, and extending southwestward probably many miles to the west of Fen-chou-fu. More description about this hypothetical anticlinorium follows.

In attempting to gather the outstanding physiographical features of northern China (see p 12) I have already mentioned that a long watershed runs between the eastern limb of the great bend of the Hwang-ho and the Fen-ho. Between Yun-ning-chou (long 111° E. lat 37° 30' N) and Wen-shiu-hsien (long 112°E lat 37° 30' N) this watershed shows a somewhat steep border on its southeastern side and gives rise to a lofty range, locally known as Shi-hsia-shan. The trend of this range is N by E according to Willis. Both Willis and Richthofen agree in stating that the main mass of the range is composed of the Sinisian limestone; but their interpretation of structure are different. ~~On account of~~ From the apparently abrupt rising of the flat-topped plateau above the plain, Richthofen infers the existence of a normal fault running along the southeastern side of the Shi-hsia-shan. The same author believes that this inferred fault is continued towards the south by the Ngo-shan fault bordering the west of the Feu-ho valley. Willis,[187] on the other hand, observed step-like folding of the Sinisian strata exhibited at the front of the Shi-hsia-shan, the beds being alternately nearly vertical and nearly horizontal. He regards the structure of the Shi-hsia-shan and its N by E extension as a large anticlinorium which is structurally connected with the Wu-tai anticlinorium already referred to. As corroberation of his hypothesis. Willis relies on the reported occurrence of gneiss and granite of pre-Sinisian type to the west of Fen-chou-fu, and the northwesterly dip of the Sinisian strata observed near Yun-ning-chou by Obrutchov. The last-named author also regards the Sinisian formation occurring in the Shi-hsia-shan as a flat-topped large anticline having a steeply inclined southeastern limb and relatively flat northwestern limb.[70] According to Willis this anticlinorium is probably one and the same fold which he is able to recognize at the Wu-tai district further northeast. Since in the Wu-tai district the anticlinorium is much broader than it is near Wen-shui-hsien, Willis infers that the axis of this gigantic fold probably pitches towards southwest.

From this interpretation of structure of Western Shan-si it follows that the younger Shansian coal bearing series would be principally found to the south of a zone at which the anticlinorium of the Sinisian strata begins to sink beneath the younger coal bearing formation. Further, it has been observed by Willis and Blackwelder that the coal bearing series occurring in the area between the Fen-ho and the Hwang-ho is folded to such a degree that dips of 10° to 20° are common. From such observations Willis concludes: "In general it seems probable that the structure of the so-called plateaus of Shan-si is marked by extensive folds having a north by east and south by west parallel arrangement". These suggestions are evidently against the old idea held by Richthofen who discusses the structure of Western Shan-si as a plateau consisting of nearly horizontal coal-bearing strata.

These conflicting opinions cannot be left uncriticised in view of their important bearing upon the coal resourceso of western Shan-si. Both Richthofen and Willis agree in delineating the structural lines (either flexure or fracture) of western Shan-si in a N by E --- S by W trend. But the strike of the rocks in the Wu-tai district involved in the hypothetical Wu-tai anticlinorium, is generally N E - S W, i.e., it is more harmoniously related to the trend of the Grill of Peking than the tectonic axis of western Shan-si. Hence it seems to be unnatural to regard the Shi-hsia-shan range as the southwestern continuation of the Wu-tai anticlinorium. Again the writer cannot agree with Willis in regarding the reported occurrence of gneiss and granite to the west of Fen-chou-fu, and the observed northwesterly low dip of the Sinisian limestone near Yun-ning-chou as facts in favour of his hypothesis. For, the exposure of the ancient gneiss and granite, and the Sinisian strata can be easily brought about by normal faults as seen by Willis himself on both sides of the Fen-ho valley. His suggestion of the probable parallel folding seems to be, however, a valuable and important one. To harmonize the opinions expressed by Richthofen and Bailey Willis, we may, with reserve, regard western Shan-si as essentially a plateau or plateaus traversed by parallel folds having N by E - S by W axial trend. Decisive conclusion can only be drawn after making a general survey of the region.

On both sides of the Fen-ho valley arcuate mountain ranges rise to great altitudes in wall-like manner. From the latitude of Ling-shi-hsien (about 36° 50' N) to the headwaters of the Keu-ho, a tributary of the Fen-ho, a range called Ho-shan stands on the eastern side of the valley. The feature of its steep front facing the valley, proves it to be a fault plane with~~out~~ little doubt. The length of this fault is approximately 50 miles- it runs almost strictly N-S with a downthrow of 8000 or 10,000 feet to the west. Both ends of this fault appear to merge into unbroken flexures. On the western side of the Fen-ho valley runs the Ngo-shan fault 98 in a N N E direction with a downthrow of 2000 feet to the east. Between this fault and the Ho-shan fault lies the rift valley or the graben of Fen-ho. The arcuate range Fong-huang-shan (see p 30), appears to be the southwestern continuation of the Ho-shan range. Its curved front which faces the Fen-ho valley, trends N.E. ~~is~~ in the northern part, southward

~~trending N E~~, but it gradually bends toward west. ~~At~~ To the southeast of Pu-chou-fu the trend of the front is W by S. This steep wall is likewise a fault plane whith downthrow on the northern side. Immediately to the south of the Wei-ho a fault of great magnitude runs ~~in a direction on~~ E by N - W by S. This fault forms the back wall of the Ta-hua-shan, with the downthrowhto the north. Its western extremity may reach as far as the south of Si-au-fu. Thence the great system of fault amalgamates with the Tsing-ling flexure. It has been stated by Willis and others that, the Ki-chou fault --- Ho-shan fault --- Fou-huang-shan fault --- Ta-hua-shan fault --- Tsing-ling flexure indicates a line of great fracture together with flexure and extends 450 miles from lat. 34^{O}N. long. 108^{O}E to lat. 38^{O} 30' N. long. 113^{O}E. Suess even believes that the fault and flexure marking the western border of the Fen-ho valley (The Ngo-shan and Shi-hsia-shan fault) extend northward as far as the plain of Ta-tung-fu. According to Suess' view the preservation of the Mesozoic coal bearing series in northern Shan-si is probably due to this line of great disturbance which throws down the coal bearing rocks on its western side.

Eastern Shan-si, namely the region which I have called the Shan-si plateau (see p 29) is a true plateau standing between the sunken areas on its western, eastern, and south-eastern sides. On its western side it rises abruptly above the valley of the Fen-ho along the line of the Ho-shan and the Fon-huang-shan faults. On the southeastern and eastern side the edge of the plateau is likewise steep and shows Coulisselike front with its convex side facing the plain of Ho-nan and the plain of S.E. Chi-li. Starting from the north of Hwai-king-fu, the front of the plateau runs in a E N E direction. To the N.E. of Wei-hwei-fu it trends N.E. To the west of Chang-to-fu the trend of the front becomes N by E. Further north, its exact shape is unknown. According to Richthofen this plateau is crowned by coal bearing strata which either form very broad and shallow folds or lie in a nearly horizontal attitude. These strata are apparently broken in successive steps with downthrow to the S.E. As indicated on Richthofen's map the steps appear to be more or less concentric to the curved southeastern edge of the plateau and converge towards the southwestern corner of the region. Suess regards this height as " a horst left in relief amid the broad sunken table land"[149]

Throughout the whole area of Shan-si the structure is relatively simple. The flat stratification of the coal bearing series, and the prevailing normal faults which preserve the palaeozoic as well as the Mesozoic coal seams, are the principal tectonic factors that have contributed to the tremendous value of the coal fields in Shan-si.

The dates of the deformation in S.W. Chi-li and Shan-si

The structure of the fundamental complex, being highly intricate, and quite different to that of the later formations, was probably produced, to a large extent, in pre-Cambrian or even pre-Algonkian time. The inferred synclinal structure of the Wu-tai formation forming the S.E. flank of the Wu-tai-shan, may also be due to an episode of pre-Cambrian earth movements, since it is apparently associated with the intrusion of the augen gneiss (see p 59) of pre-Cambrian age. The folding and thrusting which affecc the Sinisian and the palaeozoic coal-bearing series, evidently took place after the deposition of the affected coal bearing rocks. Foom the study of stratigraphy, we have reason to believe that the coal bearing series in N.E. Shan-si and S.W. Chi-li is of permo-carboniferous age. Hence the folding must have occurred in post permo-carboniferous time. The folding, of course, may have taken place more than once in a more or less similar direction. From the general concordance of the coal bearing series with the Sinisian, it can be assumed with some confidence that folding of great intensity probably did not take place in S.W. Chi-li and Shan-si during Cambrian --- permo-carboniferous period. Last of all, we have the large faults with great throws to consider. Along the northwestern foot of the Ki-chou-shan, the Hi-chou fault cuts folds of Sinisian and the permo-carboniferous rocks in a direction oblique to the axes of the latter, indicating that the fault is younger than the folds. Moreover the young features of the steep front of the ranges tend to show the recent development of the faults. According to Willis' account, the fault scarps are so young that denudation has not gone on to any extent. If we may assume that the growth of the Fen-ho is consequent to the development of th e faults in question, we may make use of the conclusion drawn by Willis from his physiographical study in northern China to attempt a more exact determination of the age of the faults. Willis attributes the Fen-ho stage (see p 42) to the beginning of the Pleistocene time. From the above assumption it would follow that the date of the faulting is probably the end of the Pliocene or the beginning of the Pleistocene. However, these are all debatable questions the writer does not intend to attach much importance to them at present.

The horst of Shan-tung.

Physiographically we have divided the province of Shan-tung into three areas. The western area with its irregular parallel mountain ranges is separated from the eastern peninsula by the central depression. Along the western border of the central depressed area the river Wei-ho flows from south to north. On the eastern side of the river the prevailing rock is gneiss and schist of pre-Sinisian age, as mapped by Richthofen; while on the western side of it, the Sinisian group crops out nearly all along the course of the river. The transition from the pre-Sinisian area to the Sinisian area is apparently sharp. We may consider these facts as sufficient to warrant the inference drawn by Richthofen and Lorenz who regard the river Wei-ho as flowing on a line of great fractures throwing western Shan-tung down against the eastern peninsula. The same view is held by Suess.[150]

As to the structure of the eastern part of the provinces, there are few data available. According to Richthofen the hils of Tong-tschou-fu, N.W. of Che-foo, and the Hsiau-tschu-shan, Ta-tschu-shan, S.W. Of Ching-tau are composed of crystalline schists and gneiss. They show a N W - S E trend. On the same authors map of eastern Shantung, to the east of Wei-ho fault, belts of "Sinich" formation with a general N E - S W trend are indicated.

The structure of western Shan-tung, namely the area lying to the west of the Wei-ho fault, is much better understood. In this area three principal tectonic features are recognizable ----- (a) Thegeneral northwesterly strike of the fundamental complex. (b) The general gentle inclination of all the sedimentary rocks younger than the pre-Sinisian, and the absence of notable difference of slip among the younger strata themselves. (c) Numerous normal faults of varying magnitude.

(a) The shearing suffered by the fundamental complex is intense; sharp contortion and complete re-crystallization are also the common features in it. Nevertheless planes of schistosity are in many cases discernible. The following actual observations will suffice to show its general northwesterly strike.

At Chang-hia district.	1 mile N.W. of Chang-hia, the gneiss strike N 10 W dip 20 W.
At Tai-shan district.	In the ravine below Heavens South Gate, gneiss and schists strike N 24 W dip vertical.
At Sin-tai district.	The north of Tsin-lung-shan the pre-Sinisian rocks strike N 40 W dip 70 - 80 S W.

The above observations are made by Willis.

(b) In the Chang-hia district, Richthofen first observed the dipping of the Sinisian strata gently towards N W.[99] Willis' observation confirms this fact; but he interprets the structure of the Sinisian strata in this district as a broad anticline,[188] the axis of which almost coincides with the highway, i.e., striking N.W. and pitching toward N.W. Local folding of the Man-to formation and the upper Sinisian beds are also observed by Willis, but they do not appear to be of general importance. Willis regards them as partial yielding of a great strut of Sinisian strata when they were subjected to compression. Apart from these instances the Sinisian and the overlying series are evenly bedded with northerly dips of 15° to 20° degrees.

(c) By for the most important tectonic feature of western Shan-tung are the normal faults. It has been discussed by Lorenz that the river Yi-ho is probably running along a line of great fault parallel to the Wei-ho fault, and the parallel mountain ranges lying to the west of the Yi-ho, (see p32) owe their origin to normal faults. Lorenz's view is to a large extent in accordance with Richthofen's and Willis' observations. The latter recognizes three sets of faults in the Sin-tai district more or less cutting across one another. Those which trend N W generally throw the Sinisian and its overlying strata down on their southwestern side; those which trend N S, as a rule, throw the Sinisian etc down on their eastern side but one exception is reported to occur, i.e., the Hwa-shan fault which throws the Sinisian down on its western side; the third set nearly runsin a E - W direction. The following are the more important ones:

1. The great fault followed by the Wen-ho valley has a length of 75 miles according to Richthofen. The amount of downthrow on its southwestern side is estimated at 8,000 to 20,000 feet

2. A series of faults pass Mei-yu-shan, Po-shan and cross the Wen-ho valley: having a length of more than 100 miles and running in a general N.S.direction.

3. Kiu-lung-shan fault runs in a direction N 80° E for more than 8 miles, with downthrow of 1,000 to 4,000 feet to the north. The Kiu-lung range is on the upthrust side.

These faults are of utmost importance for preserving the coal bearing series both of Permo-carboniferous and Jurassic age in Shan-tung. The Sinisian and its overlying series dip persistently towards the north. If they were not broken we would find the outcrops of the younger strata succeeding the older ones from the south to the north strictly in accordance to the order of their age, and the coal bearing series of the same age would be only exposed in a single belt. To the south of such a belt the coal bearing series and its overlying strata would have been denuded away. But the large normal faults running more or less along the strike of the gently inclined strata have repeatedly brought down the coal bearing series against the older groups, and thus the former has been preserved down to the present day. The coal fields of Po-shan, Yen-chuang, Lai-wu, etc. afford splendid examples. (see section

In view of the facts briefly indicated above, it seems to be justifiable to regard this tectonically independent region as a horst, ---a shattered horst, in spite of our uncertain knowledge about the structure of the transitional zone by which the protruding mass of Shan-tung is separated from the surrounding depressed plains.

The dates of the deformations The N W - S E strike, and the steep inclination of the plane of schistosity exhibited by the fundamental gneiss and schists are not shown in ~~imparted by~~ the Sinisian and post Sinisian strata. Therefore it is certain that the compression which acts in N E - S W direction and which presumably impressed a N W - S E strike on the fundamental mass, took place in pre-Sinisian time. In sharp contrast, the pre-Sinisian group is overlain by gently inclined Sinisian beds and the younger series. The latter have a general N E - S W strike according to Lorenz, while Willis infers that they strike N W in the Sin-tai district. Owing to the gentle and very broad folding of the Sinisian and the post Sinisian strata, notable discordance of bedding between them has not been observed; and hence the absence of violent orogenic movement in Shan-tung since Cambrian time is inferred. The faults affect carboniferous rocks and also the permian volcanic series. This stratigraphical evidence decisively proves the date or dates of the faulting to be post Permain. On this question Suess writes:, "The fractures in western Shan-tung are in part, at least, of pre-carboniferous age as is shown by the transgressive bedding". Suess does not give any actual examples of such transgressive bedding as

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mentioned by him, nor can the writer find any description about that kind of structure in Shan-tung given by other geologists.

From physiographical point of view, Willis compares the mature erosion of the heights of Shan-tung with the faulted Basin range of America. The latter are eroded to a less advanced stage; and since the major faulting in the great Basin region is attributed to the Pliocene time, Willis argues that the faulting in Shan-tung accompanied as it is by a more matured type of scenery may have been completed before Middle Tertiary time.

The Tsling-ling range.

The observations of different travellers across different parts of this central watershed of China have shown that this morphological unit is by no means tectonically homologous along its length, nor is it symetrical on both flanks in a single transverse section. The Tsing-ling range is therefore a complicated system composed of deformed strata. The trend of its orographic axis is generally W by N - E by S; but the strike of the strata which form the range do not necessarily agree with the trend of the present heights. The structure of the Northern flank of the range is, as a rule, relatively simple: Monoclinal flexure is probably accompanied by normal faults and minor folds of swelling-up nature which Suess calls Back-folds (Ruckfaltungen). At the northern foot of the ranges to the north of the Wei-ho (not the Wei-ho in Shan-tung) valley the strata are broken in blocks and lying essentially flat. On the other hand the southern flank of the range, particularly along the middle part of its course, conditions are entirely different: Crowded folds being overturned towards the south appear at first, which are continued by more gentle ones further south. Looking at these folds as a whole, and following them from south to north, they strongly remind us of a series of waves coming from an open ocean and being arrested by a long stretch of head-land.

A David, Loczy, Obrutchov, Richthofen, Willis have travelled across this range along different routes and made valuable observations with regard to its structure. The following paragraphs are the abstract of the description given by these geologists:

(a) Western Tsing-ling. Loczy and Obrutchov crossed western Tsing-ling-shan from "Hoj-shien" (Hwei-hsien), southern Kan-sü to "Quan-jüon-shien" (Kwang-yuan-hsien) northern Su-chuan. Their route lies in the neighbourhood of longitude 106°E. In journeying from the Lo-jan-shien (Lio-yang-hsien) to Tschau-tjen, Loczy observed the occurrence of crystalline schists, gneiss, phyllitis, and crystalline limestone, which lie in isoclinal folds,(see section No. 27) and are intruded by large bodies of diorite. He distinguishes the schists from the underlying gneiss, though they are folded together. Metamorphosed palaeozoic and fossiliferous Devonian and carboniferous are also mentioned by him occurring in the ~~broad~~ localities near the gneiss district; Southward, beyond the broad zone of granite near "Jam-pa-quan", he recognizes two anticlines of crystalline schist with a syncline of less metamorpohosed strata lying between them. Along this section of the range both Obrutchov and Loczy agree in describing the structure as that of close folding, involving overthrusts. From Tshau-tjen to Kwang-yuan-hsien, Richthofen observed overfolding with its axial plane turned towards south, and thrusting of the Silurian strata upon younger series. (see section No.31)

Richthofen crossed the Tsing-ling range from Pau-ki-hsien, to Pau-tshong-hsien,. His route lies just to the east of longitude 107E, and about 45 miles east of Loczy's mentioned above. Starting from the Wei-ho valley Richthofen noted (see section No.28) a wide zone of granite, and in association with it here and there occurs mica gneiss which merges into hornblende and chlorite gneiss. This gneiss is everywhere penetrated by the granite. South of the Twi-tszi-shan this granitic and gneissic zone is followed southward by uniform chlorite schist, the Wu-tai formation, which constantly strikes W 12 N -- E 12 S in accordance with the orographic axis of the range, and dips 50° to 70° S. Succeeding the Wu-tai schist southward, is a zone of folded middle palaeozoic and carboniferous formations extending as far as Liu-pa-ting where Richthofen met a granitic mass. This folded zone is still striking W 12 N - E 12 S. Further south follows a belt of micaceous gneiss frequently intercalated with crystalline limestone. These beds are intensely folded, and strike N.E.

(b) Central Tsing-ling   Bailey Willis crossed the central part of the Tsing-ling from Chou-chi-hsien, to

Shi-tsuan-hsien in longitude 108° 30' E. Their route lies about 80 miles east of Richthofen's, already described. In approaching the Tsing-ling-shan, from the Wei-ho valley in longtitude 108° 15' they did not find the granite as ~~shown~~ mentioned by Richthofen, but observed the occurrence of chlorite schist together with thin beds of quartzite and siliceous marble. These rocks dip towards north at first, but they soon assume a steep southerly dip which is continued southward for 5.5 miles. The strike of the rocks vary from E-W to E 10 S while the trend of the orographic axis is about E 15 N. At Liu-ye-ho, the schist group is succeeded by white quartzite and massive grey limestone folded in a syncline.

(c) Eastern Tsing-ling Loczy crossed the eastern Tsing-ling range from the Han valley to the Wei valley along the high way connecting the two valleys between longitude 112° and longitude 109°E. Travelling northward he first found Mesozoic rocks lying in basins in the vicinity of the "Sie-ho" (Siau-ho). Between the basins unaltered palaeozoic strata crop out. Further north he observed a "submetamorphic palaeozoic series" of graphitic schists, pyritiferous quartzite; yellow dolomite, which were also observed by Willis' party elsewhere in the valley of the Han, and to which they assign palaeozoic and carboniferous age. These metamorphic palaeozoic strata are followed by a broad zone of biotite schist, gneiss, granular limestone etc intruded by massive diorite. These rocks are unconformably overlain by soft sandstone and conglomerate of "Jurassic" age. Northward there follows a narrow belt of the palaeozoic metamorphic strata which again is succeeded by a broad zone of the monotonous mica schist gneiss etc with abundant intrusions. Here begins the main range of the eastern Tsing-ling which consists of "Archean Schists" and large intrusions of granite. These rocks are exposed in a zone, the trend of which corresponds to the strike of the Fu-niu-shan. (Au 5)

The Ta-pa-shan branch of the Tsing-ling-shan. The eastern prolongation of the Ta-pa-shan is also known as Kiu-lung shan Willis and Blackwelder travelled in a southerly direction across this branch of the Tsing-ling-shan from near Chon-pin-hsien, the northwestern corner of Hupeh, to the gorge district of the Yang-tze. They recognised three zones of folding, each of them is nearly parallel to the orographic axis of the range, i.e. S.E. by E. On the north, a zone of intensely folded, badly shattered, and highly altered or even Schistose rocks, forms the central ridge of the range, the folds are overturned towards the south. Following this zone southward, they found a second zone, in which, although intense folding is observable, no notable traces of dynamic Metamorphism was detected. Further south a third zone appears, which is characterized by relatively less crowded folds. Willis describes this third zone as a large synclinorium with minor folds which give rise to local heights. The southern boundary of the third zone was not observed by Willis. Judging from the general structure of N.E.Su-chuan and N.W. Hupeh, the writer thinks that there would be an insensible transition from these folds to the folds occurring at the north of Wan-hsien, the northeastern corner of the Red basin of Su-chuan. Willis compares the general structure of the Ta-pa-shan with that of the Appalachian chain where the American geologists are able to recognize three zones similar to those indicated above.

K.Vogelsang travelled across the Kiu-lung-shan backward and forward along two different routes: one lies in eastern Su-chuan and the other lies in western Hupeh. His observations ~~with regard to~~ on the structure of this mountain, essentially agree with Willis. He noted that the general orographic axis of the range runs E S E; while the strikes of the "older rocks" are, in most cases, N E: The young red sandstone formation which lies above all the highly folded rocks in this region, generally strikes N-S and E-W with gentle inclinations.[153]

From these accounts we note that the structure of the most mighty Tsing-ling range is not so simple as indicated on Richthofen's map. (see p 4)

The dates of the deformations Folding in various directions in different parts of the Tsling-ling range, affecting the older formations, (pre-Cambrian, Palaeozoic and probably mesozoic) presumably indicates that deformation took place at different geological time before the present Tsing-ling range has? begun to grow. In the western Tsing-ling Richthofen mentions that the Micaceous gneiss and limestone forming the southern part of the range strike N.E. i.e., parallel to the prevailing trend of the rocks in N.E.China and elsewhere. This strike is sharply distinguished from the E 12 S trend of the Wu-tai formation etc which form the northern part of the range in the same longitude. The presumption is strong that the northern belt of the western portion of the range consisting of the Wu-tai formation was folded in a southeasterly trend which is the prevalent strike of the pre-Cambrian rocks in Shan-tung, Manchuria, Southern Mongolia, the Nan-shan ranges, and even in the ranges near the Lake Baikal in Siberia where Obrutchov determined the strike of the ancient gneiss to be S.E. The fact that the pre-Cambrian formation in the northern part of the Tsing-ling range strikes more to the east than the general strike of the corresponding formations in other parts of N.E.Asia, may by accounted for by the necessary re-adjustment of strike resulting from the subsequent intense folding which gave rise to the present Tsing-ling range. If we regard the S.E.strike of the ancient folds and the more or less E-W strike due to the later folds as two components, we should get the resultant strike something like E 12 S, as it is actually observed in the northern part of the wastern Tsing-ling.

Arguing in this way, we are able to recognize at least three sets of folding in the Tsing-ling-shan. (a) E by S folds probably of pre-Cambrian age. (b) N.E.folds, probably of post carboniferous age, since they are harmoniously related to the prevailing trend in N.E.China. (c) More or less E - W folding which has been responsible for the growth of the present Tsing-ling range. Willis says that he has found a series of unaltered red sandstone resting upon the altered Kuei-chou series in the Tsing-ling-shan. He tentatively correlates this red sandstone with the Jurassic sandstone in the Red basin of Su-chuan, but for this correlation he is unable to produce any palaeontoligical evidance; and through this correlation he determines that the Tsing-ling folding is probably a pre-Jurassic episode. Since the Kuei-chou series to which he assigns Triassic age, is involved in the folding, he determines the age of the Tsing-ling folding as post Triassic. For the older limit we may agree with Willis on account of stratigraphical and palaeontological evidence which proves the early Mesozoic age of his Kuei-chou series (see p 226). But for the younger limit, the writer cannot readily agree with him; for the soft red sandstone might be of any age younger than Triassic for all we know.

From the stratigraphical study in the district adjoining the Tsing-ling-shan, we have reason to believe that the date of the Tsing-ling upheaval may not be as old as Mesozoic. In a number of localities in Shen-si, Ho-nan, Hupeh etc, Pliocene fossils occur in soft red sandstone often accompanied by conglomerate. These fossilferous sandstones are either lying flat, or slightly tilted. Regarding such sandy coarse material as products resulting from vigorous erosion, we must postulate an episode of earth movement of great magnitude immediately before the deposition of the essentially flat-lying sandstones. Lithologically the soft red sandstone occurring in the Tsing-ling-shan as mentioned by Willis is not unlike the fossiliferous sandstone occurring in the regions adjoining the great range. Thus the writer is led to believe that all the red sandstones referred to above were probably contemporaneous sediments formed after a period of orogenic movement ----- the Tsing-ling folding. Since the red sandstones are of Pliocene age, the movement must have taken place either in the later part of the Miocene or the early part of the Pliocene time. This inference is strengthened by the demonstrable Post Eocene age of the overwhelming Himalayan movement.[203] It is difficult to imagine that the great Tsing-ling range which runs along the northern border of the Tibetan plateau, and is parallel to the Himalaya ranges, was not effected by the same movement.

The Red Basin of Su-chuan.

If we were to seek for a good example in China to illustrate the close relation exitsting between the surface feature of a region and the structure of the underlying strata, we cannot, perhaps, find a better place than the Red Basin of Su-chuan. In connection with physiographical description, it has already been stated that the flat Red Basin is ribbed by parallel ridges, which generally trend N.E. and become more crowded towards the north eastern part of the basin. Structurally, we find these ridges correspond to more or less denuded anticlines. Although the detailed structure of each anticline is somewhat varied from one ridge to another or even from one part of a ridge to another part of the same, nevertheless the general disposition of the strata is essentially alike. The lowest formation exposed in the anticlines is believed to be of Triassic age, and the uppermost formation is a red sandstone. Apparently, they are all involved in the folds. The folds are as a rule moderately sharp; locally even miniature Alpine structure as well as overthrusting is developed. The lowest beds are folded to the highest degree. The change of dip from the lower strata to the higher ones is gradual, and the strikes of all the strata are the same in a single section. Therefore, in spite of the marked difference of dips bewteen the upper and lower formations, discordance of stratification has not been observed along the slopes of the ridges. The upper sandstone series lies horizontal in the synclines, and rarely attains a dip more than 15° on the flanks of the anticlines. The lower sandstone series often dips at angles more than 30° while the lowest strata---upper Trias, dip at angles of 60° or more.

In the southern part of the basin the axial trend of the anticlinal folds is N N E. Towards the north, they bend round in the shape of arcs with their convex sides facing N.W. At the north of Wan-hsien, lat 31° 20' N, long. 108° 30' E, the average distance between the neighbouring anticlinal axes is much smaller than it is in the southern part of the basin. From the north of Wan-hsien the strike of the strata rapidly bends towards east as the wave of folds proceeds northwards.

Ultimately, it probably merges into the folded zone of the Ta-pa-shan or the Kiu-lung-shan. The axes of these anticlines pitch towards south. Consequently, in the northern part of the basin and the ~~lower~~ limestone series ~~are~~ is laid bare, which often gives rise to the peculiar depressed crest (see p 16) On the ridges on account of the fact that the limestone offers less resistance than the surrounding sandstones to ~~the~~ forces of denudation. In the southern part of the basin the limestone is generally hidden from sight by the overlying sandstones.

In the northwestern part of the basin the structural lines appear to run in a N-S direction and shows tendency to bend towards Northwest. This is proved by the arcuate anticlinal ridges surrounding the northeastern margin of the plain of Cheng-tu.

Date of the deformation It seems to be hardly necessary to comment upon the genetic relation ~~of~~ between the folds traversing the Red Basin of Su-chuan; the harmonious arrangement as shown on Richthofen's map, the structural similarity that one fold bears to another, and the equal extent to which the uppermost red sandstones are affected, ~~all~~ tend to show that all of the folds probably have had similar history of development. To the north of Kwang-yuan-hsien, (lat 32° 25' N. long. 106° 10'E.) at the northern margin of the Red Basin, Richthofen observed the occurrence of a conglomerate which, according to the same author, forms the base of the Jurassic at that locality. On the western border of the basin conglomerates apparently occupying ~~an apparently~~ similar stratigraphical position, are also reported to occur. If these conglomerates are true early Jurassic deposits there must have been some earth movement whereby land masses were uplifted and subjected to vigorous erosion, in the neighbourhood of Kwang-yuan-hsien etc, just before the opening of the Jurassic period. But within the basin, along the numerous exposures of the Triassic and Jurassic strata, no geologist has observed the occurrence of conglomerate between the Trias and the Jurassic. They all agree in describing that, the decrease of dip from the lower strata to the higher strata is gradual. If we were to form some opinion on these data, it seems to be justifiable to assume that the earth movement which took place immediately before the opening of the Jurassic period, only lifted some parts or the whole of the bordering regions of the Red Basin; the floor of the basin probably wrinkled into folds underneath the surface of the water; and such folds might have grown since: that is to say, deposition took place while the folding was in progress. This assumption would give us a simple explanation ~~with regards to~~ for the gradual change of dip of the strata involved in the folds.

The Gorge district of the Middle Yang-tze etc.

After passing the south of Wan-hsien, eastern Su-chuan, the river Yang-tze takes an east by north course, and cuts a straight channel on the flat strata of the red soft sandstone. Flowing eastward, it cuts (1) the Fong-shan gorge, near the town of Kwei-chou-fu; (2) the Wu-shan gorge below the town of Wu-shan-hsien; (3) the Mi-tan gorge above Sin-tan; (4) the Lu-kan gorge or Nin-kan-ma-fei gorge below Sin-tan;

(5) The I-chang gorge above the town of I-chang.

Between I-chang and Kuei-chou-hsien, (lat. 30° 50' E.) there exists a broad anticline, the Hwang-ling anticline, with its axis trending N N E. Being eroded to an advanced stage, a central granitic core of pre-Cambrian age is exposed between the I-chang gorge and the Lu-kan gorge. On both sides of the central core, lies the Ki-sin-ling limestone, Sin-tan shale, Wu-shan limestone in ascending order. The observations made by Pumpelly, Richthofen, Abendanon, Bailey Willis with regard to the structure of the anticline agree essentially but differ in detail. This anticline is followed on the northwest by a syncline ----- the Kuei-chou-hsien basin, with its axis running E - W. The southern margin of this Mesozoic basin is bounded by mountains of the Wu-shan limestone striking almost E - W. To the west of the syncline, above Nan-mu-yuan, a series of sharp folds have been sketched and mapped by Willis and Abendanon. According to the latter's map, these folds are evidently parallel to those occurring further northwest towards the Kiu-lung-shan.

Between the province of Kwei-chou and Hu-nan, Wingate[154] mentions gorges similar to those in the middle Yang-tze district. If we draw a line along the eastern border of the Kwei-chou plateau, and passing the eastern terminal of the Yang-tze gorges at I-chang and those gorges mentioned by Wingate at Chen-yuan, (lat.27°N. long. 108° 30' E.) we find that this line singularly coincide in direction with the axis of the Hwang-ling anticline. The question naturally arises:

Does this line indicate a flexure or fracture or both?. The writer is unable to answer.

Further south, in the province of Kwang-si, Leclere mentions two important flexures, both of them are indicated on his diagramatic geological section across the same province.[47] The western one appears to be a broad anticlinal fold which according to the diagram, bears close resemblance, in type, to the Hwang-ling anticline; It is cut into by the river Hoa-kiang. Hence Leclere calls it Hoa-kiang flexure, the eastern flexure is called by Leclere the zone of Hou-kouang flexure. It occurs in the vicinity of Hoai-Iuen, (lat 25° 20' N. long. 109° 15° E.) and brings "pre-Cambrian" formation to the surface. The granitic mass exposed to the N.E. of Nan-ning (lat.23°N. long. 108° 20'E.) appears to fall in this zone. It is significant that the southwestern prolongation of the I-chang ----- Chen-yuan line would just fall in the Hoa-kiang flexure of Leclere.

The dates of the deformations On account of the uncertain data, deduction of the age of the deformations is not attempted.

The Si-Shiu ranges.

To the S.W. of th e Red Basin of Su-chuan granites and porphyries occur in gigantic scale. They are distributed in a belt which runs almost strictly N - S. To the west of this igneous zone, Loczy came across highly folded and faulted strata of ancient age, occupying nearly the whole region between Ta-tsien-lu (lat. 30°N. long. 102° 10'E.) and Ba-tang. (lat. 30°N. long. 99°E.) The deformation is apparently complex. Nevertheless, the strike of the structural lines is essentially N - S, viz. parallel to the trend of the orographic axis. At a place to the west of Ya-chou (lat. 30 N. long. 103 E.) Loczy mentions that "Rheatic" beds are folded together with "Devonian", while in the neighbourhood of Litang (lat. 30°N. long. 100° 20'E.) the same explorer observed a basin filled up by soft red sandstone overstepping folded and highly inclined strata of the"Wu-tai formation". To the sandstone, Loczy assigns post Pliocene age. It is hardly disturbed, evidently it is formed after the last episode of earth movement which has built the present Si-shiu ranges.

In the neighbourhood of Ning-yuan-fu (lat. 28°N. long. 102° 20'E.) Legendre[48] describes the structural lines (the axis of the folded strata), as running N - S parallel to the trend of the granitic zone which extends from Nin-yuan to Tse-ta-ti and northward. To the east of the anticlinal axis (coincides with the granitic zone,) sandstones and limestone are found which form the eastern limb of the anticline; to the west of the granitic zone a belt of mica-schist appears. The latter is cut up four times, into blocks of approximately the same size. At a great number of points along the course of the fractures, veins of auriferous quartz occur. According to Legendre the structural lines trending N - S are more well-developed to the west of the granitic zone, than to the east of it. Perpendicular to the N - S strike, there is to be noted a set of structural lines running almost E - W. One of them coincides with the lofty chain of the Ta-pao-shan (about lat. 28° 30'N. long. 102° 30'E.) a member of the Ta-shang-ling, as shown on Legendre's map. (see section No. 56) This chain appears to form the southwestern boundary of the Red Basin of Su-chuan. Along the northern foot of the Ta-pao-shan lime-stone (Triassic?) are exposed in patches; further north the ground is completely covered by red sandstone. To the south of Ta-pao-shan. the same limestone as exposed on the north of the mountain,assume great importance. They are cut up into blocks, giving rise to a very characteristic landscape of the Lo-lo district. The sandstone which underlies the limestone, is frequently exposed along the scarps of the plateaus.

Summarizing these observations the writer notes that the prevailing N - S strike in western China is accompanied by E - W strike, at all events in the S.W. of the great Red Basin.

Eastern Yun-nan.

That fractures and flexures of all grades are present in eastern Yun-nan has been proved beyond doubt. Although the structure is highly complicated. the trend of the major structural lines appear to follow a certain order. Severe deformation accompanied by thrusting is a common tectonic feature in this part of China. As a rule, the strike of the thrust planes is parallel to the axes of their neighbouring folds. **Folds.**-In the longitude of Pou-tou-ho, and to the south of the Kin-sha-kiang, the axes of folds strike E N E. This strike gradually changes both eastward and southward. Towards the east in the longitude of the Po-tche-shan [illegible] [illegible] long. E) the structural lines i.e., the axes of the folds strike almost N - S. The change of strike takes place in the district S.W. of Po-tche.shan. Proceeding southward from the lower part of the Pou-tou-ho, the trend of the axes again changes first to N E, then to N N E, This N N E trend remains essentially unaltered from Yun-nan-fu (lat. 25°N. long. 102° 40'E.) toward the south and the southeast. To the S.E. of A-mi-tchou (lat.23° 40'N. long. 103° 20'E.) another bend of the axes of folds takes place.

This bend differs from the bend in the northern part of eastern Yun-nan in that the latter bends in a northerly sense or counter-clockwise, with the convex side of the curvature pointing toward S.E.; while the former (the bend in the south eastern Yun-nan) forms an arc with its convex side facing N.W. Throughout this region nearly all the folds are slightly overturned toward S.E.

Faults Eastern Yun-nan is profoundly shattered by a large number of more or less parallel faults. The majority of them extend for a considerable distance. The one which passes the west of Sien-tien-chou (lat. 25° 35'N. long. 103° 10'E.) covers more than two degrees of latitude with downthrow to the west. To the north of Sien-tien.chou, the same fault runs almost strictly N - S; to the south of Sien-tien-chou it runs N by E ----- S by W. Branches are given off both in its northern and southern prolongations. Towards the southern part of eastern Yun-nan the faults become numerous, all of them strike N by E -- S by W. Accompanying this N by E ----- S by W group, there is a minority group, which strike more or less perpendicular to the former, viz W by N --- E by S. The combined effect of these two sets of faults is to divide the strata into rude rectangular blocks. This phenomenon is well exhibited in the neighbourhood of the Fou-sien.hu, south of Tcheng-kiang (lat. 24° 35°N. long. 103E.) and N.E. of the Red River. It is apparently due to these faults that the Triassic formations have been preserved to the east of Tchou-yuan. (lat. 24°N. to long. 103° 30'E.)

The trend of the faults sometimes agree with the axis of folding, but more often the faults cut the folds in a direction slightly oblique to the axial trend of the folds. In the extreme southeastern corner of eastern Yun-nan the strikes of the principal faults agree with the axes of the folds occurring in the same district. Their common strike is N E - S W., reminding us of the prevailing structural line in N.E. and S.E.China.

The dates of the deformations   Since the folds described above are apparently related in a harmonious manner, it would be extremely unnatural, to assume that they are produced at very different geological times. However, to avoid the risky assumption that they are positively contempaneous, we may confine our argument to a well-defined area, say the Triassic basin in S.E.Yun-nan. Here the whole of the Triassic strata are intensely folded and thrusted in a similar way, and to the equal extent, as the permian and the older formations surrounding the basin. It follows that earth movement of great magnitude has occurred in S.E. Yun-nan in post Triassic time. In the Mong-tze basin (lat. 23° 30'N. long. 103° 20'E.) and other basins, Tertiary coal bearing strata hardly show any sign of disturbance. This fact would determine the said post Triassic movement as being previous to the Tertiary coal forming period in Eastern Yun-nan. More exact determination of the date of this movement requires further data.

From stratigraphical study, Deprat is able to show that a ridge or chain came into existence at the end of the middle carboniferous period, extending from the neighbourhood of Lin-ngan (lat. 23° 40'N. long. 103°E.) to the region of Lou-nan and having a N.N.E.trend. He calls it the "chain of Tie-tchen-ho". Subsequent geological changes have put this chain entirely out of sight like so many other cases known in geological history. The writer makes special reference to this underground chain because it appears to have important bearing on the distribution of coalfields in the neighbouring regions.

The regions to the South and Northeast of the Tung-ting basin.

Hu-nan The complicated nature of the structure of the region lying to the south of the Tung-ting basin, is revealed to some extent, by the irregular contour of the country, and the large number of intrusive masses. The tectonic complexity of this region appears to increase in degree towards the southern part of the province. The meagre information furnished by Richthofen and others with regard to the structure of this part of China is far from being adequate to enable us to deduce the axes of major folds and lines of dislocation.

Thus the writer is compelled to leave this important region out of discussion.

S.E.Hupeh The triangular area confined by the bend of the Yang-tze-kiang in S.E.Hupeh appears to possess interesting tectonic features as may be inferred by the zigzag course pursued by the river Yang-tze round this region. The city of Yo-chou (lat. 29° 20'N. long. 113° 8'E.), the city of Wu-chang (lat. 30° 30'N. long. 114° 25'E.) and the city of Kiu-kiang (lat. 29° 40'N. long. 116° 10'E.) may be regarded as the three apices of the triangle. From the information furnished by Noda and Ishii, we gather that the whole area is traversed by approximately parallel folds of isoclinal nature or slightly overturned towards the south. The axes of the folds strike E by N - W by S in the western part of the triangle; but towards the eastern part of it, the axes seem to change from E - W to W by N - E by S, Near the southeastern corner of the triangle, on the southwestern bank of the Yang-tze-kiang, (lat. 30°N. long. 115° 20'E.) strata of limestone are reported to dip S.W. and strike N.W. It appears to be highly probable that each bend of the river Yang-tze on the north-eastern side of the triangle corresponds to an anticlinal fold. Of the northernmost one of these folds, the writer has some faint recollection of seeing the folded strata. They form the hills to the west of Han-yung and the central ridge across the city of Wu-chang and extends further east; the west-easterly course of the Yang-tze below Yang-lo (lat. 30° 30'N.) is in all probability determined by this E - W fold.

The axes of these folds gradually assume a E N E trend as they proceed southward i.e., towards the Kiu-gong range and the Nan-Bei range which from the divide between the province of Hupeh and Kiang-si.

The lower Yang-tze valley and S.E.China.

The structure of these regions is little known. But from what we know it may be safely said that there is a prevalent strike of different strata, which not only determines the axes of the major folds affecting the older (pre-permain?) groups, but governs, to a large extent, the distribution of the younger formations. In the following pages, I shall first deal with the scattered observations according to the province or the district in which the observations were made, and then attempt to gather the salient tectonic features characterizing the whole of S.E.China.

Kiang-si The Lu-shan mountains[32] (about lat. 29° 30'. long. 115° 40'.) standing on the northwestern side of the lake Po-yang, are formed by folded, faulted, and probably thrust strata of uncertain ages (see section No 41). It is reported that a coal bearing sandstone series is involved in the folding and an outlier of soft red sandstone lying unconformably on micaceous schists occur on the top of the mountain the faults appear to hade towards the northwest being parallel to the axes of the folds.

Along the valley of the Yuan-kiang,[141] (about lat. 27° 40' - 50' long. 113° 40' - 115° 30'.) three groups of sedimentary rocks are exposed. The "lower palaeozoic", the "upper palaeozoic" and the red sandstone formation. The "lower

"lower palaeozoic" group consists of sandstones, slates, quartzite and limestone. The slates are sometimes green and sometimes black; those which are distributed in the districts of Chang-shan-pu (lat. 27° 40'N. long 114° 35E.) and Chang-tshun-kwan, near Ping-hsiang-hsien (about lat. 27° 40' long. 113° 40) are more like shales than slates. The quartzite is either white or pink. The limestone forms relatively thin strata and is distributed in the district of Yuan-chou (lat.27° 45'N. long. 114° 20'E.), and to the east of the Siang-kiang valley (about long. 113°E). The outcrop of the limestone extends from the Siang-kiang valley towards the southwest. It has been reported that this limestone yields a rich fauna of corals, brachiopods, crinoids etc. The "lower palaeozoic" is chiefly if not entirely distributed to the south of the river Yuan and the river Lu, the latter joins the Siang-kiang at Lu-kou (lat. 27° 40'N. long. 113E.) All along the Yuan-kiang valley, the "lower palaeozoic" rocks strike E.N.E. and dip N.N.E.; whereas along the valley of the river Lu, they strike N.E. and dip S.E. Thus the lower palaeozoic group appears to form a syncline with its axis running roughly N.E. and passing the vicinity of the Ping-siang coal field.

The "upper palaeozoic" group principally consists of sandstones, shales, and coal seams with occasional limestones and conglomerates. It is widely distributed to the north of the latitude of Yuan-chou, (about lat. 27° 50') and extends westwards to the vicinity of Li-ling-hsien (lat. 27° 35'N long. 113° 25'E). In the neighbourhood of Fen-yi-hsien (lat. 27° 40'N. long. 114° 40'E.), the "upper palaeozoic" strikes S.E. and the beds are highly inclined or even stand on ends. At Ping-kiang, and Ping-siang (lat. 27° 40'N. long. 113° 30'E.), it strikes N E and dips steeply towards N.W. An anticline appears to exist in the vicinity of An-yuan (about lat. 27° 30'N. long. 113° 40'E.) with its axis trending N.E.

The red sandstone formation extends from the west of Sin-yu (lat. 27° 30'N. long. 113° 50'E.) to the districts of Yu-hsien, Liu-yang, Chang-sha etc in eastern Hu-nan. It consists of red sandstone with intercalated shales and basal conglomerate. The last named diminishes in thickness as it recedes from the mountains formed by the "palaeozoic" rocks". These red beds often show N - S strikes and gentle dip.

In the region[162] adjoining the upper valley of the Gang-kiang, shaly slates together with alternating beds of sandstone and quartzite of doubtful "lower palaeozoic" age are extensively exposed. The hills and mountains in the neighbourhood of the Gang-kiang valley are largely formed by these so-called lower palaeozoic strata. The "upper palaeozoic" formation distributed in the same region consists of sandstone with intercalated shales and limestone. The outcrop of this formation apparently occupies a much smaller area than that occupied by the "lower palaeozoic group" Unconformity is said to exist between the upper and the lower "palaeozoic groups". Between Shuei-kin-hsien (lat. 25° 40'N long. 116°E.) and Yu-tu-hsien (lat. 26°N. long. 115° 18'E), the "palaeozoic strata" strike S.E. Sharp folds have not been observed in the same district. Between Yu-tu-hsien and Gan-hsien (lat. 25° 50'N. long. 114° 30'E.); and between Gan-hsien and Wan-an-hsien (lat. 26° 25'N. long. 114° 45'E.) the "palaeozoic strata" strike N - S. To the north of Tzi-shui (lat. 27° 10'N. long. 115E.), the same strata strike N.E. Unconformably overlying the "palaeozoic group" there are patches of red sandstone formation which is distributed in the districts lying between Tzi-shui and Wan-an-hsien, it also occurs in between Fong-cheng-hsien (lat. 28° 8'N. long. 115° 40'E.) and Nan-chang-fu (lat. 28° 40'N. long. 115° 40'E.) These red beds are chiefly composed of red sandstones with intercalated layers of greenish shale and sometimes white sandstone. Conglomerates are well developed in the base of this formation. Between Shuei-kin-hsien and Yu-tu-hsien the strike of the red beds agrees with that of the "palaeozoic formation" i.e., N.W. Between Wan-an-hsien and Tzi-an-fu (lat. 27°N. long. 115°E.) the red formation strikes N - S which is also the prevailing strike of the "palaeozoic group" exposed in that district. But between Fong-cheng and Nan-chang the red beds strike N.W. differing from that of the underlying "palaeozoic group". The dip of the red strata varies from 40° to 50° at those localities where the basal conglomerate is well developed: elsewhere the dip of the red beds rarely exceeds 20°.

Kwang-tung In eastern Kwang-tung,[193] two groups of palaeozoic rocks are said to be distinguished (A) quartzite sandstone and slates without intercalations of limestone;

(B) strata similar to the group A but with intercalation of limestone. Carboniferous or Permian fossils are reported to have been obtained from the limestone. Those which belong to the group A are largely exposed in the southern part of the region. e.g. In the valley of the Tung-kiang they are exposed between the south of Lien-ping-chou (lat. 24° 20'N. long. 114° 45'E.) and the south of Ho-yuan; and in the valley of the Pei-kiang, they are frequently seen between Lien-kiang-kou and the north of Kwang-chou. These strata strike E N E; in the southern part of the~~ir exposure~~ above mentioned areas they dip S S E, while in the northern part of their exposure they dip N.N.W. Thus they appear to form an anticline on the northeastern border of Kwang-tung.

The group B is distributed to the north of the Mei-ling, viz., ~~or~~ the eastern Nan-ling range (about lat. 25°N). In the Pei-kiang valley the interstratified limestones are well developed between Shan-chou (lat 25N. long. 113E.) and Lien-ping-chou; in the Tung-kiang valley similar limestones are also exposed but their thickness is comparatively insignificant. The beds of this group B strike N.E. dip N.W. in the southern part of the area in which they are exposed; but towards the northern part of the area ~~exposure~~, they strike E S E and dip N.E.

A third group consisting of red sandstone and shale of apparently younger age than the group A & B described above is also the prevailing rock in eastern Kwang-tung. This red formation is largely exposed in the Tung-kiang valley between Ho-yuan (lat. 23° 40'N. long. 114° 40'E.) and Hwei-chou (lat23o N. long. 114° 35'E.)

In western Kwang-tung,[194] between Su-hwei-hsien (about lat. 23° 20'N. long. 112° 40'E.) and Hwai-tzei-hsien, there is a denuded anticline of considerable size, in which are exposed granite, and gneiss and schists in the centre; and a series of interbedded quartzite sand-stone and slates on both sides. The axis of the anticline runs in a N.E. direction and passes the neighbourhood of Shi-jien and Kwang-ning-hsien. (lat. 23° 40'N. long. 112° 20'.) In the vicinity of Hwai-tzei-hsien, a patch of red sandstone appears to be lying in a basin or a syncline. To the north of this patch of red sandstone, the "palaeozoic" quartzitic sand-stone and slate again appear. Their general strike is N.E; but round the margin of the granitic intrusion lying to the N.E. of Ho-hsien, the strata of the "palaeozoic" formation appear to be somewhat disturbed.

An-hwei[195] Gneiss and schists are extensively exposed in eastern Hupeh and western An-hwei. Beds of highly altered quartzite are also reported to occur in association with the schists. In the districts of Hwang-mei-hsien and Tai-hu-hsien (lat. 30° 25'N. long. 116° 25'E.) the plane of schistosity and the strike of the quartzitic strata vary from N N E to N W., and the strata dip, as a rule, at high angles. At the north of An-kin-fu, (lat. 30° 30'N. long. 117°E.) the strike of the ancient rock becomes N.E. The same strike is probably pre-valent in the gneissic and schistose rocks which form the vast watershed between the river Hwai and the Yang-tze-kiang (see p 15) The "An-kin series" of Noda which consists of alternating beds of limestone, slates, sandstone, is badly shattered by the intrusion of granite in the neighbourhood of Hong-chia-chien, N.W. of An-kin. The prevailing strike of the same series appears to be N.E. Red sandstone with basal conglomerate occur in the vicinity of An-kin. They strike N - S and dip 30E.

In southern An-hwei, viz. the area lying on the south-eastern side of the river Yang-tze, between Hwei-chou (lat. $29^{o}50'$N long.118^{o} 20'E.) and Chi-men-hsien, black shales underlie a massive series of conglomerate and red sandstone. The former are sharply folded, with their axes striking N E; the latter sometimes strikes N W and sometimes N E. But elsewhere in southern An-hwei the red beds generally strike N - S To the west of the black shale series in the neighbourhood of Li-men, a series of green shale with subordinate intercalated layers of green sandstone and black shales is exposed. To the east of the black shale series, on the divide ~~of~~ between Che-kiang and An-hwei; a series of black shale with intercalated green shale and grey sandstone crops out, which presumably answers to the formation on the west of the central belt of the black shale. They both strike N E and appear to form the two limbs of an anticline. On both sides of this hypothetical anticline a series of alternately bedded green and black shale with layers of quartzite is exposed in the neighbourhood of Kien-te-hsien, (lat. 30^{o} 8'N. long. 117^{o} 15'E.) An-hwei; and to the S.E. of Shun-an (lat. 29o 30'N. long. 119E.) and Shie-an, Che-kiang. If these shales and quartzite exposed in the two districts are really one and the same formation, it ~~may be~~ therefore should be regarded as a member of the hypothetical anticline. The hills standing on the southeastern side of the Yang-tze in the neighbourhood of lat. 30° 30'N., long. 117° 40'E. such as the Ta-hua-shan, Hsiau-hua-shan, Tung-kwan-shan and those lying to the N.W. of Ning-kwo-hsien (lat.31° N. long. 118° 30'E.) are, according to Richthofen, composed of sandstones and limestones of palaeozoic age (see section 42,43 p 155) All of the strata show a dominant N E strike.[132]

The Nan-king district[133] The structure of the hills in the vicinity of Nan-king deserves special mention. They are principally composed of palaeozoic strata, and appear to be tectonically connected with the heights of southern An-hwei mentioned above. In accordance to the bend of the Yang-tze-kiang at Nan-king, the axes of the hills also bend from N.E. to W-E towards the direction of Cheng-kiang. The effect of bending is most conspicuous on the southern banks of the Yang-tze; southward, the curved axes are soon replaced by rectilinear ones running N E - S W. It seems, as if, the N E folds in this region have been suddenly pushed against a stable block stretching in a E - W direction. This structure strongly reminds us of the curved folds occurring in N.E. Su-chuan but in a much smaller scale.

Che-kiang. In northern Che-kiang[66] an anticline accompanied by two synclines occur in the district of Chang-hua-hsien, (about lat. 30° 20'N. long. 119° 20'E.), Yu-chien-hsien (lat. 30° 15'N. long. 119° 25'E.) and Fen-shui-hsien (lat. 29° 50'N long. 119° 25'E.) The anticlinal axis passes the neighbourhood of Yu-chien-hsien and runs in a N E - S W direction. In the denuded anticlines and synclines series of limestone, sandstone and shale, and siliceous sandstone are exposed. These are mentioned in ascending order. The same anticline continues to run towards west. In the neighbourhood of Shun-an-hsien (lat. 29° 30'N. long. 119E.) strata similar to those found in the Yu-chien district strike E N E Evidently the axes have suffered bending in the region where no observation has been made. Further west the strata strike N N E. Whether these changes of the trend of the folds are due to gradual bending or dislocation of the strata is a question which cannot be answered at present.

The tectonics of southern Che-kiang is presumably complicated as a result of abundant extrusion and intrusion of quartz porphyry, granite, and other kind of igneous rocks.

Fu-kien In the province of Fu-kien the disturbance caused by igneous activity is widespread and far reaching. Here and there "palaeozoic" sandstones and slates are exposed but the strata are profoundly shattered. The gneissic group exposed along the coast of Fu-kien and in the adjacent islands generally strikes N E and dips N W. The coal bearing strata occur in synclines and they yield plant remains which are believed to be of "permian or carboniferous" age. Their prevailing strike is N.E.

From the data enumerated above, we recognize that there are two striking facts which unite the southeastern and southern provinces of China as a tectonic whole:

(1) the older rocks, probably including the early permian formation, are folded in a series of synclines and anticlines with their axes generally trending N E. This strike at once reminds us of the structure of N.E.China, the "Grill of Peking" etc. Pumpelly first recognized this important system of folds controlling the structure of Eastern Asia. He gave it the name "Sinian system of folding"[74]. Subsequent researches of Richthofen and others have greatly substantiated Pumpelly's early discovery. Since Richthofen's time, the importance of the Sinian trend seems to have been rather unduly exaggerated. K.Futterer remarks that the distribution of Sinian folds is probably not so wide towards western China as assumed by Richthofen.[24] This statement is borne out by the prevailing N - S trend of the structural lines in the west of the Red Basin of Su-chuan and in the Si-shiu ranges.

(2) Red sandstones, shales, and conglomerate occur in long belts or patches in the valleys between the mountains formed by ancient rocks (pre-permian?.). Their strikes sometimes agree with the underlying ancient formation, but more often they assume a different strike with a gentle dip.

The dates of the deformations In dealing with the structure of N.E.China, we have already determined the date of the folding which has given rise to the prevailing N E trend, as being not earlier than the end of the period during which the coal bearing series in S.W.Chi-li were formed. (see p 277) Stratigraphically, we have reason to believe that the said coal bearing series is of permo-carboniferous age (see p 206). Hence the folding in question must have taken place in post permo-carboniferous time. The general concordance of the carboniferous and permo-carboniferous strata with the underlying Sinisian formation in northern China is a fact which indicates the absence of notable folding during Cambrian permo-carboniferous period; and therefore it tends to corroberate the inference that the severe deformation giving rise to the N E trend occurred in post permo-carboniferous time. In the Ta-tung-fu coal field, northern Shan-si, Richthofen observed unconformity between "Obersinisch" or the upper Sinisian and the Liassic coal bearing series. The former is steeply folded ~~in the Sinisian trend~~ while the latter is only gently inclined. The Jurassic beds are apparently not involved in the intense folding of the Sinisian.[150] If Richthofen's observation is correct, the unconformity would enable us to determine the latest limit of the mighty folding which ~~impressed the N E strike upon~~ affects the Sinisian and its apparently conformable coal bearing series as pre-Liassic. In southern China, the research of Richthofen and others in the Red Basin of Suchuan and that of Deprat in Eastern Yun-nan have shown that two important and probably only two earth movements of orogenic nature took place during the permo-carboniferous Liassic period: The first one occurred at the end of the middle permian time, which probably lasted till the close of the palaeozoic era; and the second one marked the beginning of the Jurassic period. To compare the intensity and magnitude of these two movements in China, we may cite the accounts furnished by the above-mentioned authors. Richthofen ~~says~~ describes that the permo-Mesozoic rock, on the border of the Red Basin of Su-chuan, lies unconformably upon folded, deeply eroded and planed-off palaeozoics;[101] and that the Jurassic strata with local basal conglomerate and the underlying Trias do not, as a rule, show pronounced discordance of stratification, although unconformity is likely to exist between the two. Deprat says that in eastern Yun-nan, the massive conglomerate of upper permian age rests at once on the eroded massive permian Foraminiferal limestone and other older rocks, showing the vigorous nature of the earth movement that took place at the end of the Middle permian or the beginning of the upper permian time in the said region.

Thus in western and S.W. China we have evidence to show that the movement which took place towards the end of the palaeozoic era has probably caused a much greater tectonic change than that resulting from the early Jurassic diastrophism.

Now if we are justified to assume that the major earth movements that took place in N E China during the permo-carboniferous Liassic period also affected western and S.W. China, we would be inclined to associate the intense and far reaching Sinian movement in N E. China with the revolutionary permian movement in the western and the southwestern part of the country, for the Jurassic one is apparently of much smaller magnitude.

The next question arises: what is the relation that may exist between the prevalent N.E. strike in S.E.China and the Sinian trend in N.E.China?. Are they generated by one and the same process of earth movement?. or in other words, can we call them all Sinian trend?. Their harmonious relationship seems to demand an affirmative answer. Hence the writer tentatively assign the Sinian movement giving rise to the N.E.trend in N.E. and S.E.China to the end of the middle Permian. Later movements acting in the same direction as the Sinian might have exaggerated the Sinian folds.

The age of the "red sandstone formation" in S.E.China is not known. It may represent different geological periods, that is to say, it may not be a single geological formation. This stratigraphical uncertainty forbids us to enquire into the dates of the deformations that it has suffered

SUMMARY.

The whole of China proper is tectonically divisible into two parts. The long range of Tsing-ling which runs from W by N to E by S forms the natural divide. Large tracts lying to the north of this range are either bodily raised as plateaus or sunken as grabens, exemplifying the block-structure; while the area lying to the south of this range is characterized by waves of folds giving rise to elongated domes and basins.

Northern China In the northeastern part of northern China parallel folds occur~~.~~ which ~~They~~ trend N.E.. In the northwestern part, we find a series of folds having a general

N.W. axial trend. These two sets of folds are either deflected or cut off by the gigantic block of Shan-si, Shen-si, and Kan-su, which lies between the two folded regions. The block itself is divided up by mighty faults. The shattered horst of Shan-tung appears to be tectonically independent from the other regions of Northern China.

Southern China   In the western part of Southern China, parallel folds trending N - S form the Si-shiu ranges. These N - S structural lines are replaced by curved axes in eastern Yun-nan: In the northern part of eastern Yun-nan, the tectonic axes bend from north to S.W.; in the southern part of the same region, they curve from N E to S S W.

Arcuate folds occur in the great Red Basin of Su-chuan. The concave sides of the arcs face S.E.; northward they become more and more compressed till they completely merge into the zone of the Ta-pa-shan folds.

The structure of S.E.China i.e., the region lying to the east of the Kwei-chou plateau, is principally controlled by folds trending N.E.

The major movements which have taken part in moulding the present tectonic features of China are summarized in the next chapter with reference to geological age.

CHAPTER VII

THE GEOLOGICAL HISTORY OF CHINA.

The Earliest Era in Chinese Geology.

The early stage of the geological history of China is as obscure as it is in any other parts of the globe. From various sources of information we have learnt that there is a group of rocks in China, which is believed to be absolutely basal, extending downwards for an indeterminable depth. The nature of the rock is highly complex both in composition and structure. It ranges from holocrystalline granitoid masses to a compact and contorted aggregate of heterogeneous material. More often, however, ~~they are~~ it is characterized by the presence of dark schistose bands and lenticular layers, or by the inclusions of phacoids showing augen structure. Intrusions varying from large bosses to small dykes, from granitic to basaltic nature are frequently present; while veins of quartz and pegmatite are found in abundance. To this peculiar group of rocks the name fundamental complex or "Tai-Shan complex" has been applied.

As the name indicates, the Tai-Shan complex is not a single system. A large number of geological processes were involved in its development during a prolonged period of time. Some parts of it, no doubt, belong to the Eo-proterozoic formation (p 86) while others are clearly intrusions of considerably later dates, the marble and quartzose mica schists that are infolded in the granitoid gneiss, betray, to some extent, their original sedimentary nature. If these calcareous and micacaceous materials are true aqueous deposits, they may possibly represent the first sediments laid down after the separation of land and water.

The facts that may be of any value for elucidating the history of the development of the fundamental complex are so few, and the geological processes that might have been engaged in moulding its present features are necessarily so great, that in dealing with this mysterious page of the geological document, we cannot perhaps do better than give it the name "Complex". This unfortunate but convenient term has long been used to indicate the similar ancient gneiss and schists in many parts of the world where geology has been systematically worked. It is unfortunate because it hides our ignorance, but it is convenient because it expresses the peculiar features by which we can readily identify the basal mass that forms the earth's crust.

The complexity of structure, and the extent of deformation and alteration of the fundamental complex, further tell us that the members of the same, whatever they might be, must have been subjected to overwhelming influence of metamorphism, possibly under high pressure and heat. Judging from the reported contrast in complexity of structure exhibited between the fundamental complex and the series immediately following it, one would naturally infer that the advanced phases of metamorphism in the fundamental complex had taken place long before the first sedimentation of the next series had begun.

The world-wide similarity in Lithology and structure of the fundamental complex is one of the most striking facts known in historical geology. Van Hise has found a stronghold in this fact for his theory of "Anamorphism". It is thought by the same author and others that these metamorphic rocks are most likely of deep-seated origin and that during the very ancient time, earth movement of orogenic nature probably took place; but subsequent denudation had planed the upper zone of the deformed and otherwise altered rocks away, leaving the lower zone - the so-called fundamental complex, exposed to atmosphere before the commencement of the following period of sedimentation.

We can readily imagine that these rocks became metamorphosed under great pressure, or in other words, under great thickness of superincumbent rocks. Such a hypothesis, however, necessarily postulates a long period of time intervening between the date when the ancient rocks were formed which afterwards became the so-called fundamental complex, and the date of the deposition of the base of the overlying series. This period would be of such a length as to allow the deposition of the enormous thickness of rock and the denudation of the same, if the complex proves to contain sediments. This is not so easy to imagine, for the period involved would be surprisingly long.

Owing to the uncertainty of the geographical distribution of the true fundamental complex in China, it is practically impossible to deduce the distribution of land and sea in eo-proterozoic time. The geological forces which were then active may not have differed in kind from those which we can clearly recognize throughout the later periods but may have differed in degree. Intrusions and extrusions in this period were probably rampant. But with regard to the latter we find no trace in China. No trace of life in these rocks has been found. Indeed we cannot expect to find any record of it in such highly metamorphosed rocks even if it did exist. The recrystallization of minerals is generally complete. The writer therefore does not hesitate to state that future investigation on this group of rocks is most likely to enrich our knowledge of mineral transformation and petrological peculiarities, but with little hope of bringing any important stratigraphical and historical facts to light.

Wu-tai transgression.

Continental China during the later stage of the eo-proterozoic time, was subjected to prolonged denudation resulting, first, in sculpturing the land surface to an advanced phase and then exposing the fundamental complex. The gradual lowering of the mean altitude of land was probably accentuated by local depressions, which at once, was followed by the invasion of the Wu-tai sea. Thus the beginning of the meso-proterozoic (p ?)

period set in. As we have already seen, the basal layers of the Wu-tai system at the Wu-tai district are composed of such material as would be furnished by the fundamental complex which forms the mountains lying to the east of the locality where the lowest Wu-tai rocks are exposed. If the observations made by Willis & Blackwelder at the Wu-tai-Shan are correct, here we have strong evidence of the local invasion of the Wu-tai sea at the beginning of the Wu-tai epoch.

Unfortuna tely, the available information with regard to the nature of the junction between the fundamental complex and the base of the Wu-tai series is limited to the Wu-tai area, we cannot form any idea as to the exact manner by which the Wu-tai sea invaded the ancient land in other parts of China. Presumably the land surface had moderate relief and the transgression did not take place simultaneously. As indirect evidence for this hypothesis we find that not only the upper part of the Wu-tai formation - the deep sea facies, but the lower part - the shallow water facies is absent in many districts in Shan-tung and elsewhere. The absence of the Wu-tai rocks in these localities may be accounted for by the possible denudation subsequent to its formation; but this explanation does not preclude the possibility that the Wu-tai rocks had never been deposited in those areas or only deposited during the later part of the period.

In the Wu-tai district the quartzitic strata are gradually replaced by finer material till they become purely calcareous, which reminds us the pelagic deposits formed during other periods of geological history. This fact is, needless to say, strong evidence for the gradual deepening of the Wu-tai sea. The calcareous strata are followed upwards by conglomerate then more or less schistose grits which merge ultimately into a very fine and uniform chloritic schist. This schist seems to have attained wide development. Its occurrence in the Tsing-ling range in association with gneiss and granite has been described by Richihofen and others. The latest expansion of the Wu-tai sea is thus definitely proved.

In the middle of the meso-proterozoic period, the oscillation of the sea floor was probably followed by orogenic movement which resulted in lifting the land above water line and subjecting it to subaerial denudation. The lack of adequate data forbids us to discuss the nature of this movement, if it occurred, any further.

From the uniformity of the material constituting the upper strata of the Wu-tai formation, we infer that the Nan-tai sea was fairly deep, extensive and apparently free from the disturbing effect of currents. At the end of the meso-proterozoic time a large part of Northern and central China was under water in which quiet sedimentation continued for a period.

Post Meso-proterozoic and Pre-Neo-Proterozoic Movement and Igneous Activity.

The tranquil sedimentation at the end of the meso-proterozoic period was interrupted by orogenic movement resulting in the alteration of the distribution of land and water and the intrusion of large acid igneous magma. The Hwang-ling granite, the granite intruded into the Tai-Shan complex in the Tai-Sham district, the augen gneiss intruded into the Wu-tai formation in the Wu-tai district etc. were in all probability injected during this time. The Tsing-ling area which was under the Wu-tai sea at the end of the meso-proterozoic period became in this time mountainous districts. The principal attack of the movement seems to have directed towards N.E. or S.W., for it has impressed a N.W.-S.E. strike on the rocks affected.

Huto Transgression.

The last period of earth movement and igneous activity was again followed by quiet deposition in the Huto sea which covered a large area in N.E. China. Here begins the neo-proterozoic period. The relatively gentle inclination of the Huto strata and the very small number of basic igneous intrusions associated with them, as in contradistinction to the intense folding, and abundant acid intrusions of the Wu-tai series, show that they have suffered little disturbance since the date of their formation.

In Southern Shansi, near the Wu-tai district, the nature of the Huto rocks is reported to grade upwards from argillaceous to calcareous material. If this observation is correct, the Huto sea was evidently deepening during the Neo-proterozoic period in N. Shansi and the adjoining regions. How far the sea extended to the Southern part of China is a question which cannot be answered with safety under the light of our present knowledge. But it seems to be fairly certain that a large part of Shan-tung and the Tsing-ling range which came into exixtence as the result of the last orogenic movement, stood above the water.

Post Neo-Proterozoic and Pre-Sinisian Movement and Igneous Activity.

The continual and gradual lowering of the floor of the Huto sea in N. China seemed to be accentuated by a more general epeirogenic movement in the north, and orogenic movement in the S. of the country. This movement was again accompanied by igneous intrusions at a number of localities. They are essentially of basic composition and relatively insignificant in number.

Sinisian Transgression.

The lowering of the sea floor was still continued and the invasion of the late Huto or early Sinisian waters took place far and wide. In the early part of the Sinisian period the climate of northern and Central China became severely cold. In the N. and N.E. where there was little precipitation, the atmosphere was arid and the decomposed material on the ancient land surface remained as lateritic deposits; in the Central China where there was sufficient precipitation, glaciation took place, the traces of which can still be seen near the gorge district of the Yang-tze. It is significant that at about the same time glaciation also took place in Norway. Hence we may assume with some confidence that there was a general lowering of temperature throughout the N. Eurasian Continent (as we call it today) at the opening of the Sinisian or Cambrian time.

In N. China, the land which had been reduced to an advanced phase of a pene-plain and covered by lateritic deposits, was gradually drowned by the encroaching sea without the usual production of coarse sediments.

In S.W.China and S.E.China there is also indication of the transgression of the Sinisian sea, which was followed by gradual depression of the floor. As evidence we find that the coarse gritty deposits of lower Sinisian age are succeeded upwards by fine argillaceous material. Similar change of the nature of the deposits from shallow water facies to deep sea facies, is noticeable in many other parts of the country. The transgression of the Sinisian sea in China, is, therefore, not only of local importance but caused a wide, uniform, and progressive subsidence of the continent. Only a short time after the opening of the period the whole country was under the cover of fairly deep sea except the Tsing-ling range which probably stood above the water level as a peninsula with a few surrounding islands. It is hardly necessary to point out that the feature of the Sinisian Tsing-ling range (such as the orographic axis etc.) might be very different to that of the present Tsing-ling range.

The Sinisian sea appears to have invaded China from the N.E. where a sea of moderate depth - the Huto sea, had already been in existence before the commencement of the Sinisian period. On account of the continual deposition of the calcareous material and the very broad and gentle nature of the downward movement of the sea floor, at many places in N.E.China no striking discordance of bedding between the Sinisian and the pre-Sinisian formations is reported to be observable. But when the Sinisian strata rest at once upon the Wu-tai formation or the Tai-Shan complex, the unconformity is most pronounced in character.

The general invasion of the Sinisian or Cambrian sea into the Pre-Sinisian or Pre-Cambrian land is not only a remarkable event known in Chinese Geological history, but has been noted in many other parts of the globe. The seas which drowned so many large areas of the pre-Cambrian land and also Cambrian land appeared to be connected with one another. Fairly highly organized marine animals such as trilobites, brachiopods, etc. flourished in the extensive sheet of water in which they, no doubt, enjoyed free communication. The uniformity of physical conditions which prevailed for a long period in the open ocean, naturally tends to enhance the development of the cosmopolitan forms of life. Since then, but not until then, the continual evolution of fauna has been recorded in different geological periods in many parts of China. It is worthy of note that the apparent spontaneous appearance of fairly highly organized life in the early Cambrian time is equally conspicuous and puzzling in China as it is in so many other parts of the world. At many places the general absence of the traces of life in pre-cambrian rocks is thought to be due to ill-preservation, but this explanation does not apply to the Chinese pre-cambrian formations, for we have in China, shales or limestones underlying the Cambrian, which are the types of most likely to preserve organic remains.

Throughout the Sinisian period there was very little disturbance in China except in the S.W. where occasional oscillations of sea floor are proved by the intercalation of limestone in the lower gritty series, and grits in the upper argillaceous strata of the Sinisian formation. These oscillations were evidently only local affairs, and in no case do they seem to assume any great importance. Igneous activity was practically absent throughout the whole period.

Towards the later part of the Sinisian time, which probably includes Upper Ordovician or even Silurian, although differential movements of the sea floor became more pronounced, the essential feature of the vast ocean still remained the same, viz. the whole of China was still covered by fairly deep sea; even the Tsing-ling range which stood boldly as a peninsula above the early Sinisian water was at this time submerged. The land which had been eroded to an advanced stage, and the streams which had already reached their base level of erosian fed the open Sinisian sea with very little material. Consequently during the later stage of the Sinisian period the clear and calm sea received only meagre sediments from terreginous sources. On the other hand, where the local conditions favour the luxuriant growth of marine organisms, the skeletons of corals and brachiopods often aggregate to build up whole beds of Silurian strata such as those exposed in N. Su-chuan. Redlichia and ptychoparia which lived in the early Sinisian sea, completely disappeared; in their place, Calymene, Asaphus, Graptolites, etc. characterized the fauna of the time.

Pre-Devonian and ? Post-Silurian Movement.

Either during or soon after the close of the Silurian period earth movement affecting a large area of China took place. Northern China, viz., the area to the N. of the Latitude of the Tsing-ling-shan, was bodily raised above the sea; (In this respect the writer's opinion differs from that of Richthofen who thinks that N. China was still under the water in Devonian time),[102] while S.E. & S.W. China suffered folding of orogenic nature; the Western part of the country however, appeared to be slightly affected, for there the calcareous strata of Devonian age lie comformably upon the older rocks even without any noticeable change of lithology. This movement does not seem to be accompanied by igneous activity.

During the Devonian time in China the land lay to the north and the open ocean spread over the West & S.W. In the middle Yang-tze region the sea was fairly shallow, and the floor of it was ~~apparently~~ probably exposed to submarine abrasion. In the S.E. the sea was at first very shallow into which course sandy deposits were washed down. But at a later stage of the Devonian period, the bottom of the sea in S.E. China seems to be sinking with the consequent formation of limestone. In the province of Kwei-chou, coal seams occur in Devonian Shales, The coal is of good quality, and the seams attain workable thickness. Here we meet the first coal forming period in China.

The Chinese fauna of this period is essentially similar to the Marine Devonian facies of Europe: Aulopora, Favosites, Heliolites, Calceola, Spirifer, Atrypa etc. are the dominant forms. Therefore it is highly probable that the Chinese Devonian sea was in connection with that of Europe.

The Devonian rocks in S.W. China pass conformably upwards into the lower carboniferous. There was no remarkable change of the essential feature of land and sea during the lower carboniferous time except in the middle Yang-tze region where the sea floor showed signs of sinking, and in the S.W. of it signs of rising. In the meantime the climatic conditions became suitable for the rapid and exuberent growth of vegetation on the land; and the free communication of the worldwide carboniferous sea induced the cosmopolitan brachiopods, such as Productus etc., to flourish in the water.

In the middle carboniferous time, the sea started to advance steadily towards the N. while in the S.W. the gradual lifting of the sea floor had rendered the conditions almost estuarine. Coal seams were laid down in between sandy deposits. Here begins the second coal forming period — the longest and the most important coal forming period in China.

EARTH Movement and Vulcanicity in the Carboniferous Time.

The close of the middle carboniferous period in S.W.China was marked by intense earth movement: folding and thrusting were accompanied by the eruption of Andesitic, rhyolitic and basaltic lava, and intrusions of "labradoric" sills and dykes. It is surprising that such a violent movement and volcanic activity seem to have hardly exercised any effect in the northern part of the country where only slight fluctuation of sea level can be inferred from the insignificant beds of doubtful middle or lower carboniferous age. This disturbance was quickly followed by the next period of transgression.

Upper Carboniferous Transgression.

At the beginning of the upper carboniferous period, the whole area of Southern China started to sink, and the upper carboniferous sea progressively invaded Northern China which was then largely eroded land. The magnitude of this transgression at least matches that of the Sinisian transgression. During this time the coal forming conditions prevailed far and wide. Lepidodendron, Sigillaria, Annularia, Sphenoplyllum, Cordaites and other plants attained their maximum developement on the land, and foraminiferal fuana played the most important parts in the sea. At first, as the sea proceeded northwards, estuarine conditions prevailed in the middle and S.E. China. Accordingly the lower coal measures in the said regions were laid down. As the sea advanced further north and north-east, the estuarine conditions were shifted to the provinces of Shan-tung, Chi-li, Shan-si, Shen-si etc. Where the extensive permo-carboniferous productive measures were then formed.

After a period of oscillatory movements of the sea floor during the permo.carboniferous time, the sea again started to retreat southward, carrying with it estuarine conditions, and depositing once more coal seams in the south-eastern provinces. The upper coal measures of the lower Yang-tze region most probably belong to this period. Now another mighty orogenic movement follows.

The Middle Permian Movement and Igneous Activity.

In S.W.China we have seen that the upper carboniferous limestone passes upwards into lower Permian with perfect conformity. Indeed if not for the replacement of Fusulina which exclusively fills up the upper carboniferous limestone by an unique fauna of brachiopods characterizing lower Permian, it would be hardly justifiable to distinguish the lower Permain from the upper carboniferous in the said region. At the close of the Middle Permian time, however, revolutionary earth movement took place, producing profound change of the topographical features throughout China. This movement is particularly noticeable in Eastern Yun-nan where the conglomeratic sediments of the Upper permian age overlie the Middle permian limestone. The Tsing-ling range appears to have been brought into existence again, which separated the northern inland sea, the "Tethys" from the southern open ocean. In all probability it is largely due to this movement that the prevailing Sinian trend in China was determined, and the enormous quantity of granite and porphyritic magma in S.E.China, Western Su-Chuan, and at a number of localities in central China was poured out or injected into the palaeozoic strata.

After the Middle Permian movement, the surface features of Southern China became more varied: Estuaries of rather complicated outline probably surrounded the projecting land. Amongst them the anthracite field of Hu-nan with a peculiar lamelli branch fauna seems to be one of the most important representatives. Although this coal forming period is later than that of the carboniferous and permo-carboniferous time already mentioned, it can still be referred to the second period of coal formation in China, for the coal forming conditions probably continued since the Middle Carboniferous time.

Vulcanicity during the Upper Permian Period.

The close of the Upper Permian period, viz, the end of the palaeozoic era was marked all over China by extensive out-pouring of basic and andesitic lava. Northern Shan-tung, middle Yang-tse, and eastern Yun-nan appear to be the three principal centres. The lava-sheets are partly preserved under the cover of the Lower Triassic sediments which are generally sandy and marly, indicating more or less inland water or littoral origin. It is thus imaginable that in the Lower Triassic time southern as well as western China was strewn by large and small lakes or lagoons, while nothern China was probably under the shallow sea of Tethys.

Earth movement of any preceptible magnitude in the Lower Triassic time has not been recognised in China. The change of flora is however remarkable: Lepidodendron, Sigillaria, Sphenophyllum, Cordaites and other palaeozoic forms largely disappeared. True equiseta, peculiar genera of ferns, conifers cycads, etc. became more and more predominant.

Middle Triassic Transgression.

At the beginning of the Middle Triassic time, the comparatively shallow waters were invaded by the open Triassic sea from the S.W. Nearly at all the localities in the S.W. and Western provinces of China, where the succession of the Triassic strata has been examined and recorded, we find that the Lower Trias is characterized by sandy and marly deposits; in the Middle Trias calcareous formation predominates; while in the Upper Trias, again, we find a series of sandy and marly material. The invasion of the Middle Triassic sea apparently proceeded as far as eastern Su-chuan.

In the Upper Triassic time, or Rhaetic stage, coal seams of workable thickness were laid down in S.W. and western China. This third coal forming period was followed, for a time, by the deposition of barren sandstone and marl.

Jurassic Movement.

The beginning of the Jurassic period was inaugurated by earth movement of moderate magnitude. In S.W.China depression of the

Triassic floor was followed by the transgression of the Liassic sea. The estuaries or lagoons in which sands, muds and coal seams were deposited in the Rhaetic period, became by this time, a sea of moderate depth. This is shown by the occurence of the Jurassic dolomitic limestone overlying the Rhaetic productive measures in Kwei-chou and on the left bank of the river Kin-Sha-Kiang. While S.W.China was undergoing subsidense, many parts of Western China were gradually rising above the water. Consequently a large lake - the lake of Su-chuan, was separated from the open ocean. The nature of the movement which gave rise to the surrounding ridges, or highlands, of the lake district was probably in some parts orogenic and in the other parts epeirogenic. Where the pressure was intense and the movement was violent, we find early Jurassic conglomerate due to the subsequent subaerial denudation. The major push seems to have come from the S.E. as the Sinian movement. The tendency of it is therefore to exaggerate the old Sinian folds as well as to produce new folds having a pseudo-Sinian trend. The folding of the floor of the lake of Su-chuan was probably continued to a much later date than early Jurassic. Northern China, the area to the north of the Tsing-ling range, appears to be little affected by the early Jurassic movement.

Owing to the excessive evaporation and gradual infilling, the water in the lake of Su-chuan became highly saline; finally seams of rock salt and gypsum were deposited together with marls and shales.

In northern China, along the southern margin of the inland sea, the Tethys, coal forming conditions prevailed over a wide area in early Jurassic time. Coal seams of great economic importance were laid down in Shan-tung, Shan-si, Mongolia and other regions. This is the fourth period of coal formation in China. The fact that the monstrous flying reptiles and other peculiar saurians which characterized the Jurassic fauna of Europe have not been found so far in the Chinese Jurassic tends to confirm the existence of the inland sea, Tethys, in the Eurasian continent as we call it today. Just as the present Mediteranian separates Africa from Europe, so the Tethys separated Europe from Asia in the Jurassic period.

The last Continental Period.

As the Jurassic seas both receded northward and southward from China proper, the whole country was bodily lifted high above the mean sea level. Forces of denudation began to operate in full swing: Mountain ranges were planed down, the material thus produced being washed off by swift currents into the neighbouring valleys or basins. The country which was presumably characterized by strong relief at the beginning of the Jurassic period gradually became a vast expanse of table-land. By the cretaceous time the processes of peneplanation had almost completed their work. Geological and physiographical changes arrived at a stage of quiescence which continued for a time. Nevertheless the mean altitude of the land was still high, for even the worldwide cenomanian transgression did not invade China any further than the southern border of Tibet where true marine deposits containing cretaceous fauna have been found.

History repeats itself, towards the middle of the Tertiary time, probably oligocene or Miocene epoch, the prolonged tranquility was broken by violent attack of orogenic movement from the south. The Alps of the Himalaya rose to a great altitude in the west of China; the Tsing-ling and the Nan-ling ranges attained their imposing features across the central and the southern part of the country; large blocks of strata faulted down in northern China, to a throw of 10,000 feet or more; mighty granitic intrusion covering an area 60 miles long and 19 miles wide was squeezed out in the eastern Tsing-ling range; fissure and vent eruptions ejecting enormous quantities of basaltic lava were rampant in southern Mangolia, Shan-tung, northern Kiang-su, answering to their sister volcanoes which were then also fully active in N.W.Britain and Iceland, thus the processes of erosion once more became vigorous.

While the effect of the orogenic movement was gradually fading away, the quiet sedimentation in large and small lakes, (the relics of these lakes can still be seen in S.W. and northern China). covering the depressions was in progress. Where the water was saline, we get beds of rock salt and gypsum interbedded in sandstone and marl, where the water was sufficiently deep, lacustrine limestone was deposited. The numerous isolated areas of soft red sandstones which are so extensively developed, were probably formed subsequent to the great Alpine Himalayan uplift.

The climate during the Middle Tertiary period appears to have been suitable for rapid growth of vegetation. Coal seams were laid down both in N.E. and S.W.China. Here we come to the fifth period — the last period, of coal formation in China. This Tertiary coal is of particular economic importance in Manchuria and eastern Yun-nan at the present time.

The last phase of the infilling of the Tethys was represented by the deposition of the Gobi series which consists of clay and sandy material with occasional seams of rock salt,etc. Since this time the whole area to the north and N.W. of China became land dotted over with a large number of saline lakes.

This region well deserves the name "Han-hai" or Dry-Sea.

As the result of the disappearance of the inland sea, the atmosphere in northern and N.W.China became arid. At the end of the pliocene or the beginning of the pleistocene time eaolian conditions prevailed in northern, northwestern and to some extent southwestern China. The decomposed material was blown about, and spread far and wide over hills and valleys. Thus the formation of loess began, and has continued down to the present day. Whether there was a general lowering of temperature during this period in China[26] as in N.W. Europe and North America is uncertain, for even if the climate was severely cold, the aridity of the atmosphere could not allow the existence of large glaciers. The absence of large mass of ice in eastern Siberia today, in spite of Arctic temperature well illustrates such a case.

Since the Mid-Tertiary movement, striking tectonic changes do not seem to have taken place in a large scale. It is true that the bedded red sandstones of probable post Mid-Tertiary age are generally tilted, and in most cases the strata either strike N - S or E - W; but the dips are invariably gentle except in those places where the young sandstones were apparently deposited on the slopes of the ancient land surface. This latter fact seems to suggest that the "after effect" of the Mid-Tertiary movement probably lasted for a time during pliocene epoch. Later movement ~~and~~ or movements which have been responsible for the present physiographical features, are apparently of epeirogenic character. The sinking of eastern China or the rising of western China might have renewed the corroding power of the rivers Yang-tze-kiang and Hwang-ho, and enabled them to cut deep gorges in Western Hupeh and eastern Shan-si.

CONCLUSION.

In conclusion the writer notes with surprise, and against his expectation, that the familiar facts which have been known in the geological history of Europe and North America, are also to a large extent, represented in the course of geological development in China. Let us begin to compare the Cambrian transgression with the Sinisian transgression. The gradual deepening of the floor of the Cambrian sea both in Britain and China, is indicated by the deposition of finer material towards the later stage of the Cambrian period. In the middle palaeozoic time, the Taconian movement in eastern North America and the Caledonian movement in Scotland and Scandinavia seem to correspond to the pre-Devonian and ? post-Silurian disturbance, although Suess takes a conservative attitude in correlating these events.[136] Then came the extensive formation of coal during the Carboniferous-Permian period. The later part of this coal forming period was characterized by the mighty Hercynian or Armorican movement in N.W.Europe, corresponding to the middle Permian or Sinian movement in China. The next parallelism is the middle Triassic transgressions both in Southern China and in Southern and Central Europe; they are apparently comparable. Last of all there occurred the mid-Tertiary movements in Europe and Asia. Large areas were affected; enormous thickness of strata was thrown into Alpine folds on gigantic scale. These movements not only coincide in time and rival in magnitude, but even agree to some extent, in direction as proved by the parallel trend of some of the major folds in China and Europe produced by the movement. Further, the mid-Tertiary folding in each case was either accompanied or immediately followed by extensive out-pouring of basaltic lava.

In attempting to parallel the great movements in China with those in the western world, the writer is compelled to ask the question: Are all these great epoch-making events genetically connected? Do they have a common origin?

S E C T I O N III.

E C O N O M I C G E O L O G Y.

CHAPTER VIII

The Economic Aspect of Chinese Geology.

A. Coal Fields.

Coal is abundantly developed in China. Geologically it occurs in five periods (1) Devonian, (2) Carboniferous-Permain, (3) Triassic, (4) Jurassic, (5) Tertiary. The Carboniferous-Permain period is the most important. Next comes the Jurassic, then Triassic. Tertiary coal is worked to some extent in the northeastern corner of China Proper, southeastern Yun-nan and Manchuria, while Devonian coal is merely known in the province of Kwei-chou.

Geographically, coal is found in every province of China Proper. Nearly the whole of the province of Shan-si is a vast coal field; large areas of the province of Hu-nan and Kiang-si are occupied by coal bearing rocks. The red sandstone in the Red Basin of Su-chuan is nearly everywhere underlain by a few coal seams of workable thickness. In the southwestern provinces, viz., Kwei-chou, Kwang-si, Yun-nan, all of the five coal forming periods are partly represented by coal bearing series. A large number of isolated coal basins is known in the middle and the lower Yang-tze valley. Belts of coal bearing rocks occur in the province of Fu-kien.

The Coal Fields of Shan-tung.

The coal fields in the province of Shan-tung owe their preseveration to large normal faults. The coal bearing series is everywhere underlain by the Sinisian limestone and frequently overlain by barren sandstone and shales. In the western part of the province there are three separate basins (1) The Poshan-chichuan anthracite field lies in the Hsian-fu-ho valley. It is separated from the Hai-shan coal field by a fault running E - W. (2) The Lai-wu coal field lies in the eastern part of the valley between the Tai-shan and the Lien-hua-shan. The coal basin of Lu-tsuin at the head water of the I-ho is regarded by Koerfer as the prolongation of the Lai-wu coal field. These fields produce bituminous coal. (3) The I-tshou-fu and the I-hsien coal fields are situated in the southwestern part of the province. The I-tshou-fu coal field yields a friable earthy coal of inferior quality; and the thickness of the seams are variable, ranging from 1 to 30 m. They are arranged like fish scales. The field extends over an area of about 9.6 square miles, and is frequently flooded by the down-pouring of the yellow river. The I-hsien coal field lies to the west of I-tshou-fu and north of the town of I-hsien. It yields bituminous coal of much better quality than that of I-tshou-fu; moreover it is more favourably situated for transportation. The productive measures in this field is overlain by porphyritic sandstone and conglomerate.

The Coal Fields of Chi-li.

The coal fields of Chi-li are generally found in the synclines of the prevailing Sinian folds, i.e., folds which trend N E. In the northern part of the province several coal fields are known:-

(1) Between Shan-hai-kwan and Kao-chao, a few seams of friable anthracite crop out, striking nearly parallel to the coast of northern Chi-li and dipping N.W. The individual seams are about 5 ft thick, and the coal is not of high quality; As a rule it is used for domestic purposes. Old workings are known near Chun-ho-se, Ning-yuen-chou, Kao-chao and Shi-men-tsai.

(2) Nan-piao coal field   Parallel to the outcrop of the anthracite seams mentioned above, and about 15 miles north of it, there is a second belt of exposure of bituminous and anthracite seams which dip towards N.W. at about 30^{o} in the neighbourhood of Kao-li-ching-tze; southwestward, the dip increases and the nature of the coal changes from place to place. At Nan-piao, the seams become numerous and are of high quality; but further S.W. they entirely disappear. Irregularities caused by intrusive dykes and sills are prevalent throughout this field.

(3) Ping-kow coal field   This field lies about 50 miles N.W. of the town of Chu-ho-se and forms the gulch of Ping-kow. The coal is of sub-bituminous nature and is intercalated with grey shales and conglomerate. The coal bearing strata are broken up by E - W faults which are often the cause of the inflow of great quantity of water

in the underground workings. According to W.A.Moller, this coal bearing series is of Tertiary age.

(4) Chao-yang Pei-piao coal field   This field extends from near the town of Chao-yang to the northeastern end of Pei-piao, having a total extension of about 35 miles and being divided into three portions by igneous and schistose rocks. The nature of the coal is variable. Anthracite and bituminous coal are both known.

(5) A number of coal fields exists in the district of Jehol. In the neighbourhood of the village of Wan-ya-tsen thin seams of coal are worked for the purpose of lime-burning. N.E. of Chih-feng, in the vicinity of the Yuen-pao-shan, seams of hard brown coal having a thickness of 5 to 10 ft are overlain by gravel and sand which are about 150 ft thick.

(6) The coal field of Kai-ping is worked on modern lines, and yields excellent bituminous coal.

Three coal fields of economic importance are known in western and southwestern Chi-li:-

(1) Wang-ping coal field   About 15 miles west of Peking lies the Wang-ping coal field. The coal is sulphurous, hard and anthracitic. The main seam attains a thickness of 35 ft. The beds are either lying flat or gently inclined. A mighty series of sandstone overlies the productive measures.

(2) Tshai-tang coal field   Near the Nan-kou mountain there is an anthracite field of Jurassic age. The number of seams is reported to be no less than 9 or 10, each seam attains a thickness of about 5 or 6 ft. The difficulty of transportation has been the cause of mining inactivity.

(3) Lin-shan coal field   This coal field lies about fifty miles S.W. of Pao-ting-fu. Here, as in other cases in northern China, the productive measures are underlain by the Sinisian limestone which stands out in relief on both sides of the soft coal bearing rocks, and forms a basin with its synclinal axis running N E. The coal is worked at Mi-chang and Ling-shan in small scale.

The Shan-si Coal field and its related coal basins.

The whole of the province of Shan-si may be regarded as a single coal field. Coal seams belonging to two different geological periods are present in this vast area. The north-western part of the province, i.e., the Ta-tung-fu basin and the adjoining districts are largely occupied by Jurassic coal bearing rocks, while in the other parts of the province, coal bearing series of Permo-Carboniferous age is either buried underneath a secondary cover of sand-stone and loess or exposed on the surface of the ground. Flat stratification accompanied by large normal faults is the principal tectonic feature throughout the Shan-si coal field. Igneous intrusion and extrusion are entirely absent.

To the southwest of Pin-yang-fu, a few ridges stand above the plain of the Hwang-tu. These unburied ancient heights and their northern prolongation, the Ho-shan range, form an interesting line in the Shan-si coal field: The coal distributed to the east of this line is a pure anthracite, while that lying to the west of it is exclusively bituminous. This dividing line continues to run toward the north, and it passes the east of Tai=yuan-fu; consequently, the coal field of Tai-yuan-fu falls in the bituminous region. According to C.D.Jamison's estimate, the anthracite region alone occupies an area of at least 13,500 square miles, and the bituminous region probably covers an equal area.

The main seam of the Permo-Carboniferous coal is wonderfully persistent; it has a thickness of about 30 ft and lies 150 to 300 ft above a flinty limestone which is also fairly persistent. In the bituminous region, workable seams also occur below the horizon of this flinty limestone.

The anthracite field of Ki-chou, which covers an area of 150 square miles, may be regarded as the northeastern extension of the main coal field of Shan-si. N.F.Drake estimates the total coal reserve in the Ki-chou coal field at 3,000,000,000 tons.

Westward the Shan-si coal field extends into the southern part of the province of Shen-si, where the flat stratification and the persistency of the workable seams are maintained.

Southward, the plateau of Shan-si with the flat-lying coal seams descends to the plain of Ho-nan; there a few but important isolated coal basins occur.

(1) The Lai-neu-ho coal field   This coal field lies to the south of the Tai-hang-shan and the north of the yellow river (about lat. 35°N. long. 114°E.) The main seam is about 18 ft thick having a uniform dip 1 in 5 towards the south. The general succession of rocks is the same as in the Shan-si coal field. The coal is a smokeless anthracite of excellent quality.

(2) About 33 miles north of Nan-yang-fu, inferior anthracite is mined from two small seams of the Kin-li-shan. This small coal field is quite isolated.

(3) The coal area of Lu-shan and Ju-chou produces bituminous coking coal of ordinary purity. The productive measures overlies the Sinisian limestone. The area is roughly defined by the valleys of the Sha-ho and the Ju-ho, some 70 lis broad. Two seams are worked. (6 ft and 8 ft) In places the strata are broken up showing signs of disturbance. But as a whole, the structure of the field is favourable for mining.

(4) The Ho-nan-fu coal field lies between the Lai-neu-ho and the Lu-shan coal field. It is believed to be the northern continuation of the Lu-shan coal field, but differs from the latter in that it yields anthracite. The coal bearing strata are likewise slightly broken up.

The Coal fields of N.W.Kan-su.

A few coal fields are known in the region surrounding the Nan-shan ranges. They are worked to some extent at Shan-tan-hsien, (S.E. of Kan-tschou-fu) Sin-ho-yi and

Thung-fan-yi in the valley of the Ta-tung-ho. The coal is generally brittle and somewhat sulphurous.

The Red Basin of Su-chuan as a coal field.

According to V.K.Ting, among 146 prefectures of Su-chuan, there are 84 that possess visible coal fields. Two or three workable seams having a thickness of 3 to 4 ft each, frequently crop out on the top of the anticlinal ridges and near the margin of the basin. The coal is not of high quality, but it answers domestic purposes. Small workings are seen from place to place but nowhere do they rise to the rank of modern engineering plant.

The Coal fields of the Southwestern Provinces.

I propose to group the coal fields in the provinces of Yun-nan, Kwang-si and Kwei-chou together not because they are tectonically related but because we know very little about them. Rich coal fields no doubt exist in these provinces as can be inferred from their Strati-graphical development, and the occasional notes appeared in different mining magazines. If I may judge from the available information, I do not expect the occurrence of extensive coal fields in the province of Yun-nan, for nearly the whole province was subjected to intense tectonic disturbance in relatively recent geological time; since then a great part of the stratified rocks has been planed away. We may, of course, find local basins in the grabens or relatively sheltered areas in which the coal bearing strata are not broken up to such a degree as to entirely lose their economic value. At present a few small workings are known in this province. They are either tapping the Tertiary basins such as in the vicinity of Mong-tze or working on the Rhaetic seams which are generally composed of volatile coal and rarely exceed a thickness of 5 ft. Near Sin-chuin and Pa-che-kay good coking coal of Permain age is reported to occur. Round Tung-chuan carboniferous coal is known.

The plateau-structure of the province of Kwei-chou and a part of the province of Kwang-si seems to be a favourable condition for the preservation of slightly disturbed coal seams. According to Wingate, and Leclere, bituminous coking coal crops out to the N.W. of Kwei-yang and between Kwei-yang and Kwei-ling. They are largely of Rhaetic age. The coal fields in these provinces are hardly touched.

The Coal fields of Hu-nan and Kwang-tung.

Richthofen divides the coal field of Hu-nan into three areas (1) The Liu coal field lies in the south-western part of Hu-nan. It is apparently the continuation of the coal field of Kwang-si. Near the divide between Kwang-si and Hu-nan, the coal bearing strata are folded or otherwise disturbed; the coal is of inferior quality. Northward, however, the quality of the coal inproves. In the vicinity of Liu-yang, the coal is an impure anthracite occurring in numerous seams, each of them attains a thickness from 3 to 6 ft. The coal bearing strata are highly inclined. Small workings are found in a few places but they never reach a depth of more than 200 ft.

(2) The Siang coal field lies in the valley of the Siang-kiang and the valleys of its tributaries. The coal is generally bituminous and contains iron pyrites. Good coking coal has been worked in recent years at Siao-hua-shi, (near Siang-tan)Lung-chau, Lai-ling, Ma-tou and Chun-chou. (central Hu-nan) The Ping-siang colliery on the border of the Kiang-si has gained great importance within the last 15 years. It commands the chief supply of the Yang-tze towns. Collieries are also seen in the Hen-chou district on the Siang-kiang.

(3) The coal fields of Western Hu-nan spread over the region of Shin-chau-fu and Yuen-chau-fu. They are little known, and hardly touched.

In the province of Kwang-tung, bituminous coal occurs in the valleys of the rivers Ui-lung and Sik-cheung, Lu-kuong, Pun-yu, Ping-hai, Fa-yuen and Mei-tan-tsang. Details of these coal fields are not known.

The Coal Fields in the middle and lower Yang-tze valley.

In the province of Hu-peh, two coal fields are known:
(1) The Djn-nan coal field lies in southwestern part of the province. It covers the district of Hsin-shan, Tze-kuei, I-tu, Chang-yang and extends southward into the province of Hu-nan; thence it probably joins the coal fields of western Hu-nan. This coal field is not a single basin, but includes a number of small basins; The structure of these basins is unknown. Seams of bituminous coal having an average thickness of 4 ft crop out in many localities.

(2) The coal field of S.E. Hu-peh extends over the districts of Pu-chi, Tshong-yang, Hsin-kwo, Ta-yeh and Kwang-ji. Both anthracite and bituminous coal are known in this area. The coal bearing rocks are generally folded together with the underlying limestone; the axes of the folds strike approximately E - W.

The coal fields of the province of Kiang-si are divisible into four areas (1) A belt of coal bearing rocks containing thin seams of coal runs along the eastern foothills of the Lu-shan and dives underneath the Po-yang lake; it reappears at Pun-tseh-hsien on the eastern border of the same lake. (2) The second area covers the district of Lo-ping, Teh-hsin, Yu-kan, Wan-nien. (3) The third area lies on the west of the Gang-kiang, and embraces the districts of Sui-tshou-fu, Fon-chen-hsien, Lin-kiang-fu, Sin-yu-hsien and the whole valley of the Yuan-kiang. (4) The fourth area lies in the neighbourhood of Kwang-sin-fu and extends into the province of Che-kiang forming the Kin-hua and Chu-tchou coal fields.

In the province of An-hwei, there is an anthracite field extending over the districts of Su-sung, Tai-hu, Kwei-che and Hwai-ning. The coal bearing strata are highly folded and often dislocated. The coal is rich in sulphur.

No important colliery is known throughout this coal field. In southern An-hwei, coal occurs in the vicinity of Ning-kwo-hsien. The nature of the coal and the extent of the field is unknown.

Coal seams occur in the neighbourhood of Nan-king and Chen-kiang. They do not appear to be economically important.

The Coal fields of Che-kiang and Fu-kien.

In the province of Che-kiang, anthracite occurs near Tung-lu-hsien. This anthracite field is disturbed by complex tectonic movements. It lies between a belt of Palaeozoic rocks on the northern side and a granitic mass on the southern side. At Yi-u-hsien, east of Kin-hua-fu, bituminous coal has been worked for a long time past. In the districts of Si-an-hsien, Kiang-shan-hsien and Tai=chou-fu both anthracite and bituminous coal seams are known. As a whole h the province of Che-kiang is least important among all the provinces of China Proper as far as their Coal-producing capacity is concerned.

In the province of Fu-kien, Ishii describes two belts of coal bearing rocks: The first extends from Kien-ning-fu Yen-ping-fu southward to Ta-tien-hsien, Chang-ping-hsien, Lung-yen-chou and Yun-tin-chou. At Lung-yen-chou, it forms a syncline containing beds of anthracite. The second belt extends from Tsong-an-hsien, Shau-wu-hsien to the districts of Tai-ning and Kien-ning. This belt also contains anthracite The coal seams usually attain a thickness from 3 ft to 6 ft and they are as a rule, much broken up.

The Annual production of coal in China.

The annual production of coal in China has not been accurately recorded. The figures quoted below are merely intended to show the approximate quantity.

The following estimate was given by T.T.Read in the year 1911.

Province	Anthracite (in tons)	Bituminous (in tons)	Sub-bitum. and lignite (in tons)
Manchuria		25,000.	1,000,000.
Chi-li	840,000.	2,090,000.	150,000.
Shan-si	4,000,000.	25,000.	
Shen-si		500,000.	
Kan-su		500,000.	
Shan-tung	300,000.	500,000.	
Ho-nan	1,000,000.		
Su-chuan		500,000.	
Kwei-chou		250,000.	
Yun-nan		300,000.	
Che-kiang		10,000.	
Kiang-si		700,000.	
Hu-nan		200,000.	
Kwang-tung		50,000.	
Kwang-si		100,000.	
Other prov.		100,000.	
Total.	6,140,000.	5,900,000.	1,150,000.
Grand Total		13,190,000.	

The Ministry of Agriculture and Commerce of the Chinese Government gives the following figures for the year 1913.

Shan-si	2,868,000.
Chi-li	2,701,000.
Shen-king	1,805,000.
Ho-nan	1,463,000.
Shan-tung	1,120,000.
Hu-nan	1,120,000.
Su-chuan	1,992,000
Kiang-si	949,000.
Hsin-kiang	600,000.
Hei-lung-kiang	230,000
Kweq-chou	100,000.
Shen-si	100,000.
Hu-peh	100,000.
Yun-nan	86,000.
Fu-kien	50,000.
Ki-rin	44,000.
Kan-su	30,000.
Kiang-su	25,000.
Kwang-tung	12,000.
Kwang-si	10,000.
Che-kiang	10,000.
An-hwei	10,000.
Total.	14,515,000. tons.

The Caol Reserve of China.

The available quantity of coal that China has in her store cannot be estimated even to the first approximation at the present stage of our knowledge. Attempts, however, have been made by different authors. They give us very different figures. Two instances are cited below:

Name of Province.	Estimate due to N.F.Drake. (in metric tons)	Estimate due to Inouye. (in metric tons)
Shan-si	714,340,000,000,	1,200,000,000.
Yun-nan	300,000,000,000.	
Hu-nan	90,000,000,000.	17,000,000,000.
Su-chuan	80,000,000,000.	15,000,000,000.
Kwei=chou	30,000,000,000.	
Chi-li	22,668,000,000.	3,080,000,000.
Ho-nan	9,275,000,000.	200,000,000.
Shan-tung	7,083,000,000.	650,000,000.
Kan-su	5,129,000,000.	
Kiang-si	3,395,000,000.	
Mongolia	1,200,000,000.	
Kwang-tung	1,009,000,000.	
Shen-si	1,050,000,000.	
Kwang-si	500,000,000.	
An-hwei	187,000,000.	
Hu-peh	117,000,000.	
Fu-kien	25,000,000.	80,000,000.
Che-kiang	24,700,000.	120,000,000.

Kiang-su	10,000,000.	
Manchuria		1,208,000,000.
Total.	996,612,700,000.	39,973,000,000.

The quantity of coal stored in the Shan-si coal field is probably overestimated by Drake, for he chooses his data for calculation from Richthofen whose opinion is decidedly too liberal. On the other hand, the coal reserve of the provinces of Che-kiang, Fu-kien, Kiang-si, An-hwei, Mongolia is probably under-estimated by Drake, for Wang, after a careful survey, reports that the coal field of Fon-chen, Lo-ping and Fu-liang in the province of Kiang-si alone contains approximately 500,000,000. tons, and that there are two billion tons of coal lying in the coal field of Western Mongolia. For the provinces of Yun-nan and Kwei-chou, Drake's estimation is based on the data given by Leclere whose description of the coal field in these provinces is by no means elaborate. Inouye's estimation is still less satisfactory. It should be noted that both Inouye and Drake have left the coal fields of northern An-hwei out of consideration.

Assuming that the plus and minus errors of Drake's estimate of the whole country cancel each other, we have some 1,000,000,000,000. metric tons of coal in China waiting for mining exploitation. The present world consumption (before 1914) of coal per annum is roughly 1,000,000,000. tons.

If there is no change of the rate of consumption in future, the Chinese coal alone would be able to supply the whole world for 10 centuries. It is also interesting to note that the coal reserve in the whole world, as may be gathered from the report published by the International coal cencus in the year 1913, is approximately 7.5 million million tons. If this figure and the figure given by Drake are something approaching the truth, nearly one seventh of the total coal reserve in the world would be found in China.

B. Oil Fields.

Petroleum are known to occur in China in two areas (1) In the coal field of Shan-si and the adjoining regions, (2) In the Red Basin of Su-chuan.

(1) The Shan-si area In the year 1914, an agreement between the Chinese government and the Standard Oil Company of America was signed with the object of opening up this oil field. At first, a geological examination was made in the neighbourhood of Cheng-teh-fu, southwestern Chi-li, but the opinion of the experts was adverse. Subsequently attention was turned to Yen-chang in the province of Shan-si and extensive drilling operations were conducted. Though seven wells were drilled to a depth of 3,000 ft, very little oil was found, consequently the work was suspended. Negotiations were continued for some time between the company and the government, with objects not made public but finally the matter was definitely abandoned by the Stan-

dard Oil Company. The results obtained in Shan-si by the company appear to be at variance with local experience, for oil had been obtained in marketable quantities, and the government is said to be still keen to carry on the work.

Generally speaking, the tectonic features of the Shan-si area do not seem to be favourable for preserving large quantity of liquid and gaseous fuel, for the stratification of the rocks is essentially flat, and the strata are divided up by large normal faults, the edges of the dislocated blocks are often exposed on the side of the plateaus.

(2) The Red Basin of Su-chuan The occurrence of petroleum and natural gas in the Red Basin has been known to the inhabitants of Su-chuan since time immemorial. They are usually found in the salt wells in more or less quantity. Sometimes they are utilized as fuel for evaporating the brime, but in most cases, the petroleum is thrown away as waste. Such petroleum-brine wells are found at the following localities:-

Shi-yu-kow, south of Chung-king-fu. (lat. 29°42'N long. 106°30'E)
Northeast of Pong-lai-chien, between She-hong and Su-ning.
San-yuan-chang, east of Yen-tin. (lat. 31° 15'N. long. 105° 32'E.)
Ji-tien-sze, northeast of Jien-yang (lat. 30°30'N long 104°35'E)
Pong-chi-hsien. (lat. 30° 45'N. long. 105° 52'E)
Yun-hsien (lat. 29° 35'N. long. 104° 30'E.)
Tze-liu-tsin (lat. 29° 25'N. long. 104° 50'E.)

In the vicinity of Tze-liu-tsin and Yun-hsien, there are some 3000 to 5000 wells reaching to a depth of 2700 to 3000 ft. The brine usually contains 15 to 50% of petroleum. When the proportion of petroleum exceeds 50%, the liquid is thrown away being unprofitable to be used for the extraction of salt. From Tzu-liu-tsin to Kia-ting-fu (lat. 29° 30'N. long. 103° 50'E) A large number of salt wells have been sunk. The mixture of salt solution and petroleum obtained from these wells shows a gradual increase of the proportion of petroleum towards the direction of Kia-ting. The quantity of natural gas escaping in the district of Tzu=liu-tsin is reported to be no less than 20,000 cub. ft. per hour.

In dealing with the structure of the Red Basin of Suchuan, I have mentioned the fact that the whole basin is traversed by a series of sharp anticlinal folds accompanied by broad synclines. The axes of these folds generally run in a northeasterly direction; and the folds pitch towards the S.W. According to Abendanon. Since there is no great difference of altitude between the northeastern part of the basin and the southwestern part of it, Abendanon's statement would mean that the southwestern part of the folds is less denuded than the northeastern part; therefore oil is more likely to occur in the southwestern part of the basin underneath the unbroken domes than in the northeastern part where the anticlines are truncated. This inference seems to agree with the known facts, for the majority of the brine-oil wells are situated in the southwestern part of the basin.

C. Ore Deposits.

Iron.

Two classes of iron deposits are distinguishable in China:- (1) massive deposits associated with igneous intrusion. (2) bedded deposits, some of which are formed by the process of metasomatic replacement, others are of unknown origin. To the former class belongs the famous deposit of Ta-yeh, S.E.Hu-peh. Deposits of similar origin but of varying size are extremely numerous especially in the lower Yang-tze valley. The ore is usually found in the contact zone between dioritic intrusions and the upper Palaeozoic sediments, e.g. the Fusulina limestone. Within the contact zone contact-metamorphic minerals such as garnet, etc are often developed. Besides the Ta-yeh deposit, the principal deposits of economic value are the Ao-cheng (Wu-chang) deposit in Hu-peh, the Cheng-men-shan deposit near Kiu-kiang in Kiang-si, the Tai-ping and Fang-chang deposits in An-hwei, the newly discovered deposit near Nan-king, the Tsi-nan and Ling-cheng deposits in Shan-tung and the An-chi deposit in Fu-kien. Among the smaller but well-known deposits belonging to this class, the deposit of Tung-kwan-shan in An-hwei and the Likwoyi deposit in Kiang-su may be mentioned.

Extensive bedded iron deposits of sedimentary and metasomatic origin occur in the Shan-si and the Ho-nan coal fields. They are found between the Shansian system and the underlying Ordovician limestone as lenticular masses, and sometimes in pockets in the Ordovician limestone. The ore is either limonite or hematite. V.K.Ting estimates the average thickness of this bedded ore at 30 c.m. or less, and he states that the irregular nature of the deposit excludes the possibility of mining on modern scale. This iron field is worked in two districts in Shan-si in small scale: The one in the Ping-ting-chou district forms a narrow belt running across the Shan-si railway, the other lies in the districts of Luan and Tze-chou, S.E.Shan-si. The Shan-si iron industry is believed to be the oldest in the world, but the general prospect, as pointed out by Mr. Ting, does not seem to indicate a hopeful future.

In association with the pre-cambrian rocks in northern China, there occurs well-bedded iron ore. The best example of this type is found at Lan-chou near the coal field. Unfortunately the percentage of iron is rather low. The well-known iron ore of Ping-siang in Kiang-si and that of the adjacent district Yu-hsien in Hu-nan are believed by V.K.Ting to be of the same nature as the iron ore of Lan-chou

V.K.Ting estimates the total iron reserve in Shan-si at about 300 million tons; nearly the whole of this quantity is unsuitable for modern mining. The reserve of the other deposits altogether amounts also to 300 million tons, of which at least half can be worked by modern methods. The total production of pig-iron in China in 1915 was about 300,000 tons, of which 136,541 tons was from the Hu-yang iron works, and 29,529 tons from the Sino-Japanese Coal Mining Co. in South Manchuria. The rest are attributed to the small native furnaces in Shan-si, Su-chuan, Hu-nan, Yun-nan etc.

Gold.

Rich gold deposits have not been found in China in great quantity. Judging from what we know, China is not likely to be an important gold producing nation. Roughly speaking, we may divide Chinese gold deposits into four classes: (1) Recent Alluvium, (2) Ancient Alluvium, (3) Tertiary sandstone (4) Reef deposits in pre-Cambrian gneiss and metamorphic rocks. Nearly all the gold mines in Manchuria and outer Mongolia belong to the first class. The four great rivers in Manchuria, the Amur, the Ya-lu, the Tu-men, and the Liao-ho drain large areas covered by gneiss and granite, whence the gold has been washed down together with other products of erosion, into the tributary valleys. All the great gold mines in the province of Hei-lung-kiang are situated on the right bank of the Amur river, those of Kirin along the tributaries of the Ya-lu and the Tu-men, and the mines of Mukden in the Liao-ho valley. In outer Mongolia, they are in the valleys of the Iro, the Shara, and the Kurduri, all of which are tributaries of the Selenga, which flows into the lake Baikal. Alluvial gold is found in the upper Yang-tze between Yun-nan and Su-chuan and the smaller streams in Shan-tung, Ho-nan and Jehol.

Examples of the second class are found on the banks of the Ya-lung river in western Su-chuan.

The Gobi series of Tertiary age is widely distributed in northwestern China,. In the Nan-shan region, it is often found to be auriferous.

In western Su-chuan particularly in the neighbourhood of Ning-yuan, Kiang-si, Hu-nan, Fu-kien, northern Chili and Shan-tung auriferous quartz veins occur in gneiss and schists almost invariably associated with granitic intrusions. The famous Ma-ha mine in Su-chuan and the Ping-kiang mine in Hu-nan are both working on gold deposits of this class.

In 1915, China produces 200,000 oz. of gold; over half of this quantity came from Manchuria.

COPPER.

Copper ores are widely known in China, but few have been proved of value. V.K.Ting, classifies Chinese copper deposits into five classes: (1) Magmatic segregations, e.g. The Permain basalt of Yun-nan and the Tertiary porphyry of northern Chi-li; (2) contact deposits, e.g. in the Ta-yeh and Hsin-kwo districts in S.E. Hu-peh and the government mine of Pang-shih in Kirin; (3) replacement and fissure veins e.g. the Tung-chuan-fu mines in Yun-nan and in the district of Huei-li in Su-chuan; (4) impregnations exclusively found in the pre-Cambrian crystalline rocks of southern Shan-si and northwestern Hu-peh; (5) Sedimentary deposits, occurring in the Lower Triassic sandstone in Yun-nan and Kwei-chou, usually in the form of malachite. Among these five classes, the third is most important. The ore belonging to this class is of high grade, usually above 8%, and the possible reserve is large. Those belonging to the fourth class are usually of low grade but sometimes rises to respectable dimensions. The rest may be regarded as economically unimportant.

The present yearly production of copper in China is about 2,000 tons, half of this amount is supplied by the province of Yun-nan.

TIN.

Tin deposits occur in many localities in the province of Yun-nan, Kwang-si and southern Hu-nan. In the majority of cases, the ore is in the form of cassiterite and is largely associated with granitic intrusions. In the districts of Ling-wu and Kiang-hua, southern Hu-nan, tinstones occur as lodes in limestone and granite. In the district of Ko-kiu, eastern Yun-nan, which is the most important of all the tin-producing districts known in China. It is a residual deposit; the minute crystals of cassiterite are scattered through the limestone not far from the granite and are usually too poor to be mined. But as the limestone is weathered away, a red residual clay is left in which tin ore is thus concentrated.

Tin is at present the most important metal produced in China. The production in 1915 was nearly 8,000 tons, over 80% of this quantity came from Ko-kiu.

ANTIMONY.

China occupies an unique position in the production of Antimony. Since 1908 the country has produced more than 50% of the world's total yield. In 1913 China produced 13,000 tons, that of the whole world being 20,000 tons, while in 1915 China's production increased to 20,000 tons. The mineral stibnite together with small quantity of antimony oxide is widely distributed in the province of Hu-nan. The districts of Sing-hua, An-hua, Yi-yang and Pao-ching in the valley of the Tze-kiang, are the principal centres. The best known deposit is that of Shi-kung-shan where the ore beds occur brtween the quartzite and the overlying limestone which are either Lower Carboniferous or Upper Devonian. These beds are folded into anti-clines and domes with which the ore appears to have a constant relation. In the AMi-chou district in Yun-nan, antimony deposit is reported to occur in the Triassic formation.

Zinc, lead and Silver.

These three metals usually associate with one another (1) They occur in the Archean gneiss in northern Chi-li and northern Shan-si. The ore is not found in quantity but rather rich in silver, e.g. the richest galena from Jehol contains 100 taels per ton. (2) They occur in the Palaeozoic limestone. Those belonging to this class attain a much wider distribution than the former class. But usually they are rather poor in silver content. (average 16 taels per ton) The government mine of Shui-kou-shan in Hu-nan is working on large pockets in the limestone, and the ore is said to be a mixture of galena and blende. Silver-bearing zinc carbonate and lead carbonate is worked in a small scale at Kung-shan, in the province of Yun-nan.

In the year 1914 China produced 6,000 tons of zinc and 5,300 tons of lead, as to the quantity of silver there is no accurate record but it probably does not exceed 50,000 oz. the annual production of these metals in China is said to be steadily increasing since 1914.

MERCURY.

Mercury usually occurs in China in the form of sulphide. It is widely distributed in the province of Kwei-chou and is also known in the province of An-hwei.

Tungsten.

The increasing demand of Tungsten for the manufacture of Tungsten steel in the recent years has led to the discovery of Wolfram deposits in a few places in southern China. Small quantities of this mineral have been brought to Hong-Kong for sale. It is said to have been derived from Cheng-chou, southern Hu-nan, but the exact locality is unknown. The analysis of the said material shows that the mineral probably occurs in the form of Wolframite. $(Fe.Mn.WO_4)$. Similar ore is obtained from Wai-chou on the West River, Hai-fong, and Ho-chi. (about 120 miles N.E.

of Liu-chou, Kwang-si.) In the last mentioned district Wolfram occurs in veins traversing a "quartz-rock"

D. Underground Water.

It is practically inpossible to discuss the conditions of the underground water in various parts of China at the present stage of our knowledge. A special investigation on this vital problem is urgently needed, particularly in the vicinity of densely populated towns where the people are not over-anxious in choosing the quality of the water that they drink. The cause of raging epidemic is often traced to the free use of contaminated surface or shallow well water, the latter is often so shallow that it cannot be properly called a shallow well.

In spite of the inadequacy of data, I venture to make a few broad remarks on the water-bearing nature of two young geological formations in China; On these formations the principal towns are situated. In northern China we have the Hwang-tu which spreads far and wide over hills and valleys. It sometimes rests on the semi-permeable pre-Cambrian gneiss, schists and schistose quartzites, and sometimes on the soluble Sinisian and pre-Sinisian limestones. Occasionally it is underlain by porous sandstone of permo-mesozoic age. The Hwang-tu itself is of very inconstant thickness, and is, in some cases, intercalated with sands and gravels which are important permeable membranes in the homogeneous Hwang-tu. Although the texture of the Hwang-tu is exceedingly fine and therefore highly resistant to the percolating water, it is by no means imperveous, for wells reaching to a depth of 30 to 40 ft, in the plain of Hwang-tu often yields respectable quantity of water for drinking and agricultural purposes. The singular vertical structure (see p 244) of this material affords a passage for the surface water to travel down, which viciates the quality of the water underground. Thus it is not always safe to obtain drinking water from the Hwang-tu by means of shallow wells, especially when the wells are found to yield too freely. The city of Peking is situated in the Hwang-tu plain, there the Hwang-tu is intercalated with several beds of gravels and sands. These perveous intercalations crop out in the hills to the west of Peking, and form the intake of rain water. The thickness of the Hwang-tu in the plain is probably more than 800 ft, the gravels and sands are lying in the middle part of the whole formation. Thus artisian condition appears to prevail under the city of Peking. Wells reaching 300 ft have been sunk in Peking, and they have yielded fairly large amount of drinkable water.

In southern China the young red sandstones (p238) are distributed over large areas. The sandstones are often intercalated with shales which either form an imperveous cover or an inperveous bed. In the province of Hu-nan, underground water is frequently found to gush out from the fissures of the red sandstone. The town of Cheng-tu, (the provincial capital of Su-chuan) the town of Chang-shan (the provincial capital of Hu-nan) and the town of Nan-chang (the provincial capital of Kiang-si) all stand on this red sandstone formation. It is to be expected that large amount of water may be drawn from the underground source for supplying these towns.

E. Miscellaneous economic products.

In the pre-Cambrian formations in China, talc-schist occasionally occur as fairly thick layers, the pure variety is used for the manufacture of soap-stone or steatite. Large flakes of mica, chiefly biotite are found in the neighbourhood of Kau-chou, eastern Shan-tung. They occur in association with the pre-Cambrian schists. The Sinisian limestone of northern China is sometimes used as building stone and sometimes for lime-burning. The Kan-ling slate in the province of Kiang-si is largely composed of greenish clay-slates. In the middle of this formation there are a few beds of persistent and uniform porcelain-rock inter-bedded with sandy clay-slate; each bed of the porcelain-rock is about 3 or 4 ft thick consisting of extremely fine clays in which are scattered minute crystals of Kaolimite. This porcelain-rock is worked in the district of Kin-teh-chien, which is noted for the production of excellent China-ware.

The crystalline Devonian limestone in the southwestern provinces is quarried as marble, particularly the black variety, and used for building and ornamental purposes. The Fusulina limestone in S.E.Hupeh is used for lime-burning and cement-making in the middle Yang-tze region. In the lower Yang-tze region the Fusulina limestone is also used for lime-burning; but here it contains "firestones" which appears to be composed of fine argillaceous or calcareous material permeated by bituminous substance. It is combustible, for it is used for lime-burning. A careful analysis may prove that it contains valuable substance such as petroleum.

The flinty limestone and the sandstone which occur in the productive series of the Shansian system in the provinces of Shan-si and Chi-li, form hard and durable building stones. They are often used in the collieries of Shan-si and Chi-li for shaft-lining. Good fire-clay and pottery clay also occur in the Shan-si coal field. Those occurring in the neighbourhood of Tze-chou are of the highest quality.

In the Red Basin of Su-chuan, rock salt occur in the Triassic formation. It is pumped up from many thousands of salt wells. The salt wells are particularly abundant in the district of Tzu-lin-tsin where the annual production of salt amount to 300,000 tons supplying 1/5 of the total quantity of table salt needed by the nation. Similar salt basins are known at He-tsin and Lang-tsin, S.E. of Ta-li-fu (Yun-nan)M there the rock salt occurs in association with gypsum in the Upper Permain formation. Gypsum is also obtained in the Permo-Triassic formation between Kwei-yang and Kwei-lin in the province of Kwei-chou.

The Gobi series in northwestern China often contains various kind of salts such as rock salt, gypsum, sodium and potassium nitrate, etc. The gypsum deposit in the district of You-chen, Central Hu-peh, is believed to occur in the Red sandstone of Tertiary age.

In the alluvial deposits in the neighbourhood of I-tshou-fu, Shan-tung, diamond has been worked. The diamond is a black variety suitable for industrial purposes. A German firm attempted to locate the exact position of the deposit but did not succeed.

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