PALAEONTOLOGY IN CHINA

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Fossils have been known to the Chinese as objects of curiosity for thousands of years. Who it was that first attributed medicinal potency to these objects that were found in the soil and weathered rock material, and at what period of Chinese history such belief led to active collecting and barter of these fossils, is unknown. It is a very ancient practice—so much is certain; and the exploitation of deposits of "dragon bones" especially for the teeth, is a recognized and legitimate pursuit, and the secret of the location of such deposits is handed down from generation to generation.

Most of the "dragon bones" and "dragon teeth", in North China at least, are either of late Tertiary (early Pliocene *i.e.* Pontian) age or belong to the early part of the Quaternary. The most abundant types of the larger vertebrates, whose teeth are especially valued, are horses (especially *Hipparion*) rhinoceroses of various genera, deer, and some others. These bone-fragments and teeth are even now purchasable at Chinese medicine shops in villages as well as in the larger cities, such as Shanghai, Tientsin, and Peking. It is from such sources, that the first collection of vertebrate fossils was obtained which was scientifically studied and described by the Munich Palæontologist Dr. Max Schlosser.

But it is not only the remains of vertebrates that can thus be obtained. Fossil Brachiopoda, especially those of Devonian age, which are the best preserved and most abundant fossil in South China, are eagerly collected and sold to the native drug-stores as stone swallows or Shih-yen.¹

Weathered outcrops of Devonian and, sometimes, other rocks, from which fossils may easily be collected, are well known to the natives of those districts in which they occur. They have indeed been considered as of sufficient interest to be mentioned in the histories of the districts, and the wise collector will first of all consult these local histories for any record of outcrops of fossiliferous rocks.

But we must not suppose that fossils have been regarded by all Chinese as miraculous or wonder-working objects of unknown origin. Chinese philosophers have not overlooked them and as early as the 12th century, correct notions of their origin and significance had been arrived at. Chu-Hsi wrote in 1200 A. D., "In high mountains there are shells. They probably occur in the rocks which are the soils of older days, and the shells once lived in the water. The low places became high, and the soft mud turned into hard rock." This, it must be noted, was two and a half centuries before the birth of Leonardo da Vinci to whom is commonly credited the first correct interpretation of the origin and meaning of fossil shells.

Although the ancients knew about fossils, and had correct notions regarding them, no attempt at a scientific study of these objects was made. These men were philosophers, not scientists. In China, philosophy is old, but science is young. Half a century covers the period during which Chinese fossils were studied scientifically, and less than a decade measures the period when Chinese themselves began the systematic study of their fossil faunas and floras.

¹A considerable series of such brachiopods (*Spirifer, Cyrtiopsis, Atrypa, Schizophoria, Yunnanellina*, etc.) has recently been purchased by my students in Peking, Shanghai and elsewhere, to supplement the collections made in the field, for a monograph on these fossils which is now passing through the press.

Almost all of the Chinese fossils brought to Europe or America in the early days were collected by missionaries and other travellers from Chinese medicine shops. Some of these were described in Belgian, English, Italian and German literature by such men as de Koninck, Davidson, Woodward, and Crick, and the Italians, Martelli and Pellizzari, all of whom confined themselves to invertebrates. Smith-Woodward studied some of the fishes and Schlosser described the first mammals. Systematic collecting did not begin until the year 1860 when Raphael Pumpelli, the American geologist, made the first geological explorations in China. His collections, however, comprised chiefly plant remains, which were described by Dr. John Strong Newberry.

The epoch making systematic investigation in Chinese geology was that of Freiherr Ferdinand von Richthofen, during the years 1869 to 1871, followed by the publication of that great work, "China-Ergebnisse eigener Reisen und darauf gegründeter Studien" in 5 quarto volumes, several of which were issued after the death of the great explorer, together with two large atlasses of maps. This work has become a classic of Chinese geology and an inexhaustible mine of information. Two of these volumes are devoted to Palaeontology: Volume 4, chiefly prepared by the late Professor Emanuel Kayser of Marburg, with contributions by G. Lindström, Wilhelm Damas, Conrad Schwager, A. Schenk. and later emendations and revisions of parts by Fliegel; and Vol. V, the work of the late Prof. Fritz Frech of Breslau

Following Richthofen came the expedition of the Hungarian count Belalt Szechenyü in 1877-1880¹, the geological and palæontological work of which was done by Ludwig von Loczy, who himself described many fossils in Vol. III of the report of that expedition. Here too, other collaborators contributed descriptions of selected groups, among them

¹Reise des Grafen Bela Szechenyii in Ost-Asien.

Lorenthy on the Foraminifera, Frech on the corals,—Schenk on the plants, Neumayer on the Quaternary and recent mollusks, and Koken on the vertebrates (Palæontographica). Other expeditions which brought back fossils and found space for their description in their own or other publications, were those of Futterer, Obruschew, Sven Hedin from Tibet, and the Merzbacher Tienshan expedition of 1907 to 1908. Among the collaborators in the descriptions of the fossils obtained by these expeditions were: Potonie, Schellwien, Gröber, Keidel. Krasser, Krenkel, and Leuchs.

Independent collections made by themselves or others were also described by Bergeron, Lorenz, and Monke, and by the Japanese palæontologists, Yabe and Hayasaka. Finally Mansuy and Cowper-Reed described many fossils from Yunnan, which were collected by Deprat and others, and by Coggin Brown, while Zeiller described many coal plants from South China. It must not be forgotten that many of the fossils described in the Palæontologia Indica came from the Tibetan border, if not actually from that territory.

The last two important foreign expeditions designed chiefly for the collection of fossils, were those of Bailey Willis and Eliot Blackwelder under the auspices of the Carnegie Institute of Washington, and the Central Asiatic expedition of the American Museum of Natural History, and Asia Magazine under Dr. Roy Chapman Andrews. The former devoted itself exclusively to invertebrates, which were subsequently described by Walcott, Weller and Girty, while the latter paid chief attention to vertebrates, though a rich invertebrate fauna of Permian age was collected, which has furnished the material for one of the final volumes now in press, the preparation of which has been entrusted to me. Unlike the collections of all previous expeditions, the invertebrate material on which this volume is based has been deposited in the Museum of the National Geological Survey in Peking by the Andrew's expedition.

The Chinese Geological Survey was organized in 1013. but active work did not start until 1916, as the first three years were required for the proper training of a staff of field From the beginning, palæontology was regarded geologists. as an important branch of study that should be undertaken in connection with the work of this Survey. When the Survey was organized there were no adequate courses in geology at the higher institutions of learning in China and none in palæontology. Three Chinese geologists. Dr. V. K. Ting, Dr. W. H. Wong, and Mr. H. T. Chang took charge of the new Survey. They had received their chief training, the first in Great Britain, the second in Belgium and France, and the third in Japan, but all had traveled more or less To train an adequate staff of field geologists extensively. was the first step to be taken, and these men, in 1913, organized the school of geology, in which for three years graduates of Chinese colleges and middle schools received an intensive training in the necessary subjects. The graduates of this school were appointed on the staff of the Survey. In this school Dr. V. K. Ting taught, among other subjects, the first course in palæontology given in China.

In 1914 Dr. J. G. Andersson, the noted Swedish geologist, director of the Geological Survey of Sweden and geologist of Swedish Arctic and Antartic Expeditions, was called to China as adviser to the Ministry of Mining. From the first Dr. Andersson kept up a close relation with the geological Survey, though he was not an official member of it. With his aid and under his supervision, the Museum of the Survey was organized.

Dr. Andersson early recognized the importance of the rich deposits of Pliocene and early Quaternary vertebrates, which for so many years had been exploited for "dragon bones" and "dragon teeth". With the co-operation of the director of the Survey, Dr. V. K. Ting, and aided by a grant from a Swedish Committee organized for the purpose under the patronage of H. R. H. the Crown Prince of Sweden, Dr. Andersson began to collect these vertebrate remains, which were sent to Sweden for study and description by specialists under the general direction of Dr. Carl Wiman of the University of Upsala.

The first extensive collection of Chinese invertebrate fossils made by a Chinese, was that made by Dr. V. K. Ting in 1914 in Yunnan province. This collection was sent to the United States for identification, but some years later it was returned only partially identified, and most of it has since been monographed here. Dr. Ting had conceived the plan of publishing a series of palæontological monographs patterned in a general way on the Palæontologia Indica, and to be issued under the general title of *Palæontologia Sinica*. This was divided into four series as follows: series A., fossil plants; series B., fossil invertebrates; series C., fossil Vertebrates; and series D., ancient Man.

When I was called to China in 1920 to develop the work in palæontology and to train Chinese students in that science, I was given charge of series B, and in that series the first fascicle of the *Palæontologia Sinica* appeared on April 28, 1922. This dealt with the Ordovician Fossils from North China, though previously two short papers on other Chinese fossils had appeared in Bulletin 2 of the Geological Survey. This was the beginning of palæontological publications in China, and since that time 37 fascicles of the Palæontologia Sinica have appeared, with a total of 3604 quato pages, 796 text figures, 339 plates, 107 tables and I chart. A more detailed analysis of these monographs will be given later.

Other foreign palæontologists have from time to time been called to China to carry on special work. First among these was Dr. Theo Halle of Stockholm, Sweden, who made extensive collections of fossil plants though many of these were lost by the foundering of the ship on which they were being carried to Sweden. Dr. E. Norin, a Swedish geologist, made other extensive collections of plants, and still others were made by Dr. Andersson, and by a field party under my direction. Many of these have now been described by Dr. Halle in a completed volume of the *Palæontologia Sinica* Ser. A. and others are being studied, Dr. Norin also made extensive collections of invertebrates from the Carboniferous rocks of Shansi and these are now being studied in the Palæontological Laboratory of the Survey, and several groups have already been monographed. For several years Dr. Otto Zdansky made collections of vertebrates in North and and Central China, and since his return to Sweden he and other European palæontologists have published a number of monographs on this material in the *Palæontologia Sinica*.

In was during his exploration of the bone caverns of Choukoutien near Peking, first discovered by Dr. Andersson, that the teeth of a hominid, the now famous Peking man Sinanthropus pekinensis Black and Zdansky, were found. This led to an extensive exploration of these caverns, carried on jointly by the Geological Survey and the Rockefeller Foundation, and this has already brought forth many interesting remains of this remarkable early pre-human. Τo undertake a part of this work of exploration, another Swedish palæontologist, Dr. Birger Bohlin, was called to Peking, and it was he who discovered the tooth that eventually was made the holotype of the new genus and species Sinanthropus Two Chinese palaeontologists Dr. Young, and *bekinensis*. Mr. Pei, and several Chinese geologists have also been active in the exploration of these deposits. To carry on the work of preparing and studying these fossils a Ceno-Psychozoic Laboratory of the Survey was established and placed under the charge of Dr. Davidson Black who is describing the hominid material from these deposits, while the work on other fossil vertebrates will be directed by the eminent French palæontologist Dr. Teilhard de Chardin. In this laboratory active work in the preparation of the vertebrate material is now going on, and this, with the large new palaeontological laboratory of the Survey on Ping Ma Sze, the center of work on Palæozoic fossils, and the affiliated Peking Laboratory of Natural History on Kaka Hutung, where Tertiary and Recent mollusca are being studied, has concentrated the work of Palæozoology in the Survey's hands in Peking. It is hoped that before long a part of the work in palæobotany may be carried on here as well.

In this connection must be mentioned the recent establishment of a palæontological department at Sun Yat Sen University in Canton, and the coming to China of a famous German palæontologist, the late Professor Dr. Otto Jaeckel. of Greifswalf. Dr. Jaeckel had labored successfully in his new field for nearly a year, when coming to Peking for the meeting of the Geological Society of China in February 1929. he contracted pneumonia, to which he succumbed, not however, before he had taken a most active part in the meetings of this Society. His death is a great loss to science and a greater one to Chinese palaeontology. The impetus, however, which his coming has given to palaeontology in the South, bids fair to have lasting results, and we may look to the time when another center of palæontological research will be firmly established in South China. Finally in Central China, palæontology is becoming an important part of the research work carried on under the auspices of the National Research Institute.

Nor may we forget the trail-breaking work of Peres Licent and Teilhard de Chardin in the palæontology of Palæolithic man, and above all the great work begun by Dr. J. G. Andersson in the collection and study of Aeneolithic man in China, which has already led to the publication of a number of important monographs in series D, of the Palæontologia Sinica, on the implements and artifacts by Dr. Andersson and others, and the human skeletal remains by Dr. Black.

It is thus apparent that palæontological research, unknown in China ten years ago, has now become firmly established. Meanwhile active collecting is constantly going on in many parts of China, by the geologists and palæontologists of the National Survey, as well as the various provincial surveys and a number of the institutions of higher learning. Nevertheless the field is vast, and its cultivation has only begun, and many decades must elapse before the palaeontological treasures of China are unearthed and will become adequately known.

The solidarity of Chinese palæontology has further been enhanced by the founding of the Palæontological Society of China, as a branch of the Geological Society of China, founded some seven or eight years ago; there are at present about 25 active Chinese-trained palæontologists,¹ several of these having carried on graduate work in vertebrate palæontology in Europe and the United States. These with the foreign palæontologists, now resident in China, form the membership of this new society.

The training of independent research workers in palæontology, requires, of course, much more than is given in the palæontological courses included in the curriculum of the geological departments of our universities. This is not always understood by the educational authorities and sometimes not by the students themselves. All too frequently men are called upon to teach the subject of palæontology which they had studied in courses during their undergraduate years. These courses should be considered merely as a preparation for palæontological research, and no one should be required to teach the subject who has not spent a number of years in active research work in palæontology.

It is an unfortunate fact that we have at present in China no real university, that is, an institution which gives not only lecture and laboratory courses in science, but also provides facilities for research for post graduate students. The

¹The most brilliant of these, Mr. Y. T. Chao, has recently been murdered by bandits while engaged in field work in Yunnan. His untimely death is an irreparable loss to Chinese science and especially Chinese Palæontology. He is deeply mourned by all his colleagues and all who knew him.

Geological Survey, recognizing this lack of research facilities has organized what is essentially a department for graduate work in geology and palæontology. The most promising undergraduate students are enrolled for two years of graduate study, and training in research under adequate supervision. If during those years, these students prove themselves competent and capable of developing the power of independent judgement, they are taken on as junior members of the staff and given the opportunity to carry on independent research work in co-operation with the chiefs of the departments.

This is properly the function of the universities and the next step in the higher education in China, should be the establishment of such graduate schools at institutions of higher learning. In geology and palgeontology, and in the sciences which are prerequisite to a proper preparation, China has probably a sufficient number of men to equip one univer-It is hardly necessary to emphasize, that no one who sity. is not himself an investigator and no one who has not already produced scientific work of merit, is fitted to be on a staff of a university where the training in research work is a primary The present tendency in China to scatter its able men object. among a number of institutions which call themselves universities, though not one has a real right to that name, is to be deplored. No real progress will be made in China in higher education and the training of research workers until China's first true university is established. Such a university must have an adequate staff gualified to direct and supervise the resarch work of graduate students. Nor must students be permitted to think that they are gualified to carry on independent research work after they have completed their four years of college training. Such students are all too frequently called to organize courses and give instruction in their subjects, at institutions ambitious to broaden the scope of their curriculum. Whatever may be said of other subjects, certainly in science, no individual is fitted to direct the activi ties of a department, who has only pursued the undergraduate work in his subjects.

During the nine years that I have been training Chinese students in palæontology, I have produced two men whom I feel are adequately prepared to organize palæontological departments elsewhere in China, and these two students have not only studied with me during their undergraduate years, but since their graduation have for many years carried on research work in the laboratories of the Geological Survey.¹ I have many other students who have completed their undergraduate work and who give promise of becoming leaders in Chinese palaeontology, provided they are given the opportunity to carry on research work for at least a number of years in connection with our unofficial graduate school at the But, if these men are called to other Chinese insti-Survey. tutions to organize departments of geology and palaeontology, and become responsible heads of such departments before they have become thoroughly grounded as research workers, and have developed a research spirit which will remain with them through life. I for one refuse to be held responsible for the instruction and training given in these sciences at those institutions. I should deplore the fact that promising young men are ruined by being burdened with responsibilities which they are as yet unable to shoulder, and by being accorded scientific recognition which they have not earned. This is all the more to be regretted when these young men are well fitted to earn such recognition by the successful accomplishment of scientific labors, were they given the opportunity to under-I am prepared to assert that China has many take them. young men, capable of becoming eminent as scientists, but I am equally prepared to say that the great mass of these young men will never achieve eminence, if responsibility and recognition is thrust upon them prematurely. Nor do I think that the present practice of sending numbers of newly fledged graduates to America or Europe for graduate training in science, will bring results commensurate with the expenditure involved. Indeed I hold that too many promising young men

¹One of these was Mr. Chao whose death has been noted above.

are spoiled by premature contact with western educational institutions. No one should be sent abroad for scientific study, who has not already become well grounded in his particular subject, and has pursued it to the full extent possible here in China. Only such students should be sent abroad who are ready to profit by several years of contact with specialists in the subject which they have chosen. In other words, no student who has merely acquired knowledge and has not yet made a beginning in research work is fitted to profit by contact with foreign scientific men.

Again it is not the institution which the student should select when prepared to go abroad, but the men who can carry him forward in his own science. It is the men pre-eminent in the science chosen by the student, that should attract him, not the institution, no matter what its general reputation. The practice of the Geological Survey of sending abroad only proved men should be adopted by other institutions, and no institution of learning should be encouraged to send men abroad, unless it has a graduate department of its own in the subjects in which it trains its candidates for foreign study. And finally no student should be sent abroad unless he has a plan of study and is prepared to devote strenuous years to his particular subject.

Returning to the science of palæontology, we may note that the intensive training which is judged necessary for the development of palæontologists, has already produced very gratifying results. I have previously referred to the *Palæontologia Sinica*, the first number of which appeared in 1922. Since then thirty-seven fascicles of this work have appeared, of which 13 fall under series B, "Fossil Invertebrates of China," with 5 others in course of publication. The total number of Chinese species and varieties of invertebrates described in these numbers is 526 of which 301 are new. If we add the number of species in the five fascicles now in course of publication which is 387 of which 295 are new, the total number of invertebrates described in these fascicles will be 913, of which 546 are new. The total number of invertebrate fossils previously described from China by foreign palæontologists in other publications is 2,294 of which 651 are new.¹

The results of less than ten years of palaeontological work in China, compares thus most favorably with that done by foreigners on China fossils during the last sixty years. Of the 13 fascicles of series B of the Palæontologia Sinica 8 or about 62 per cent are the work of Chinese palaeontologists trained in China, and this number will be greatly increased when the monographs now in course of preparation are published. So far, most of the monographs in the other three series have been written by foreigners, who were entrusted with this work by the responsible authorities. But a beginning has been made in the field of vertebrates where several important monographs have been published by Chinese palæontologists, though only one of these has appeared in the Palæontologia Sinica. Other are, however, in preparation, and with the establishment by the Survey of the vertebrate laboratory and the extensive collection of Cenozoic and Psychozoic vertebrate remains, including those of primitive man, there has come a new impetus for work in vertebrate palæontology in China.

When it is realized that the field is of vast extent and the study of fossils in China has only been begun, it will be seen that we are just entering upon an era of fruitful palæontologic work in China, and there is opportunity for many generations of adquately trained Chinese palæontologists.

But the description of the Chinese fossils is only the beginning of the work in palæobiology which must be undertaken in the future. As the fossil fauna of each geological system becomes fully known, its relation to the faunas of the same system in other parts of the world must be made the subject

¹These data were kindly collected for me by Mr. Y. S. Chi, Secretary of the Palæontological Society of China.

of intensive study. Foremost among the problems to be considered, is that of the center of evolution and migration of the faunas. We know now that throughout geological time most, if not all of the great oceans which still exist, were the centers of evolution of marine organisms. As the opportunity was given for the ocean waters to enter the geosynclines and epeiric seas of the continents, in the sediments of which the only remains of marine organisms known to us are preserved, each ocean sent its respective quota. Sometimes the fauna of one ocean basin predominated and at others that of another, and sometimes there was a comingling from two or more centers of distribution. The problem then becomes one of evaluation of the separate faunas. This can only be accomplished if the specific determination is a very critical one. No analysis of morphological characters that does not take into consideration the ontogony of the individual, can serve this purpse. Often a complete restudy of the faunas of other regions becomes necessary, when the original characterization is based on superficial or adult characters. Nor must we leave out of consideration the evidence for palæogeography of the period, furnished by stratigraphical studies, for this must give us a primary clue to the probable connection of the inland water-bodies that have furnished our fauna, to the great oceans of the period. The highest Palæozoic or Permian faunas of China may serve as an illustration.

The original Permian system was differentiated in northern Europe, where it has long been known as the Dyas, because of its two-fold development. This is best known from Germany, where the lower part is an almost barren sandstone, the Rothliegendes, while the upper part is a limestone series, the so-called Zechstein which carries marine fossils in its lower part, while its upper portion includes the great salt and potash deposits which have made the formation economically as well as scientifically famous. In England red continental sandstone predominates, the limestone having a subordinate development. In the eastern end of the basin, along the western front of the Ural mountains in Russia, the series shows a more diversified development and it is from this region, the government of Perm, that the name Permian is derived. The series begins with a limestone which rests with a disconformity and hiatus upon Middle Carboniferous The existence of this hiatus was not recognized by the beds. early investigators and hence they concluded that these beds represented Upper Carboniferous. They, however, contain a fauna, which is almost wholly new to the region, although in the beginning, some form indigenous to the basin were mingled with the new element. Nothing was known of the origin of these new biological elements, until the corresponding deposits of China were studied, when it became apparent that this fauna was an invasion from the east, and represented late palæozoic organisms of the Indo-Pacific realm, whereas those of the north European basin were at home in the Boreal realm, whence they sent migrants, not only into the Russo-German basin, but also into central North America. The pathway of this first great invasion of the Permian fauna from the east, has now been sufficiently traced for us to realize that it was one of wide extent. Not only did it submerge the Ural barrier, which up to that time had efficiently separated the Russian basin with its Boreal waters from the Asiatic region, but it also invaded the Mediterranean region of Europe, either along a pathway now occupied in part by the Himalavan mountains or through the Nan-Shan geosyn-On the other side of the Pacific, these waters entered cline. Texas and New Mexico, but did not join the interior seas which covered portions of the Rocky Mountain states and which were an extension of the Boreal realm of the time.

After this first wide-spread invasion by the Indo-Pacific seas, the Ural barrier again became influential in re-establishing the isolation of the Russian Basin. In the strata which succeed the Schwagerina limestone (the record of this first invasion) the Boreal fauna again becomes prominent. But the descendants of the migrants of the invaders from the east still lingered on, though in a diminished number of species, and their remains were buried with those of the indigenous fauna in the Artinskian sediments which follow upon the Schwagerina limestone since the latter had been erroneously thought to represent a closing Carboniferous formation, and since the Artinskian enclosed many of the same species, as well as those typical of the Boreal Permian, it was regarded as marking the transition from the Carboniferous to the Permian, and was commonly referred to as Permo-Carboniferous. Now that we know that the older formation is not Upper Carboniferous but represents the invasion of the early Permian fauna from the east, we recognize that the Artinskian is not Permo-Carboniferous, but marks the re-establishment of the reign of the Boreal fauna in the Middle Permian deposits of the Ural region. This Boreal fauna was thenceforth confined by the Ural barrier to the Russian basin and its extensions, a fact clearly indicated by the character of the sediments. The Indo-Pacific sea on the other hand, continued to cover various parts of China and hence we find in the higher Permian beds of China these Pacific faunas represented in their essential purity. It is the study of the Chinese Permian that has enabled us for the first time to differentiate and evaluate this distinctive fauna of one of the largest of the Permian oceanic basins.

The problem of the origin of faunal elements which make their appearance suddenly in the strata in many regions of the earth also calls for solution by the palæontologist interested in marine faunas. A pertinent example is furnished by the class of graptolites, those ancient representatives of the modern hydrozoa, which make their appearance abruptly in the basal Ordovician strata, wherever these are known to occur. Since these organisms, at their appearance, already show a high degree of development, it is evident that they must have undergone evolution during a long period of time, preceding that in which they first appear, and that this abrupt appearance must be due to wide dispersion at the opening of the Ordovician period, from a region hitherto isolated, in which they had undergone their development. Moreover, the period in which such development took place must have been during Cambrian time, which is the period immediately preceding the Ordovician, unless we can show that there is a long time interval between the Cambrian and Ordovician deposits, which is nowhere represented by fossiliferous sedi-But if these organisms developed during the Camments. brian period, their remains should be found in Cambrian strata, which is not the case. Hence the only conclusion that we can draw is that the Cambrian strata of the world as we know them, were deposited in basins from which the graptolites were excluded by efficient land or climatic barriers, for since these organisms led a floating life, nothing but such a barrier would prevent their entering the Cambrian seas, wherever these were open to invasion. Of the known basins in which the Cambrian strata of the world were deposited. none could be the home of the graptolites in Cambrian time, since their remains are absent from the Cambrian strata. though they commonly occur in the overlying Ordovician beds. Therefore, we must search for a basin from which Cambrian strata are still unknown and the only one that satisfies the requirements is that of the western Pacific. No Cambrian strata referable to the western Pacific are at present known, but it is known that the barrier which separated the Pacific from the Indian oceans throughout Cambrian time, disappeared at the opening of the Ordovician. We are therefore led to believe that it was in the Pacific basin that graptolites underwent their early development, and that it was the opening of the barrier between the Pacific and the Indian oceans, that permitted them to enter the latter basin and, from it, the inland seas, which then extended from China to Europe on the one hand, and to the Boreal region and the interior of North America on the other. Cambrian strata of the Pacific realm should contain not only a Cambrian fauna but also the remains of the ancestral graptolites, as well as those of many other groups of organisms, which make their abrupt appearance in Ordovician time, and whose genetic relations to the Cambrian types, have heretofore eluded investigation.

Still another problem of biological significance is that of the differential evolution of parts of a once wide-spread fauna, which have become separated by rising continental barriers. In the early Tertiary, a continuous water body extended from the Mediterranean sea of Europe across Egypt, and the site of the present Red Sea to the Indian, and thence to the Pacific basins. Free migration was possible, and as a result there was more or less widespread uniformity of faunas, though of course local faunal groups existed everywhere.

But when the great world revolution which produced the Alps, the Himalayas and many other mountain ranges began, a barrier arose, separating the Mediterranean from the Indian basin. From that time onward, the basins have remained essentially distinct, and the dismembered faunas underwent independent development.

This is best illustrated by the molluscan elements of the If we except circumpolar types, which could venture fauna. both into the Atlantic and the Pacific, we find that the molluscan fauna, though related in the two oceans is nevertheless distinct, having not a single species in common, though most of the genera are represented in either basin. To understand this independent evolution, we must go back to the Miocene or Middle Tertiary era, where this differentiation of a former homogeneous fauna, first became manifest. It has been stated that in the Miocene and other Pacific regions, about 75 per cent of the Mollusca are still living, whereas the Miocene of Europe scarcely contains 25 per cent of living organisms. It is probable that the investigation into the ontogeny of the Pacific forms, both fossil and recent, will greatly reduce this number of species.

But such study to be of any value, and if it is to reveal the manner of differentiation of faunas, must be a compre-

696

hensive study of the entire Indo-Pacific Molluscan fauna from the Miocene to the present, and a comparison of the Miocene species with their Oligocene and Eocene ancestors as well. And since the personal equation invariably enters into the question of such a study, the entire problem must be investigated under the direction of a single individual, though the number of his aids need not be limited. But whoever undertakes such a comprehensive study, must be qualified for it by prolonged training in the ontogenic methods of investigations of the molluscan shells. Such work in order to be successful must be concentrated in a single scientific center, where vast collections of both recent and Tertiary Mollusca of the Indian and Pacific realms can be brought together. Here is an opportunity for China to undertake the investigation of a world problem, and one that will lead to the positive solution of questions concerning the method and perhaps the causes of evolution of organic forms.

Palæontology has a great future in China. Not only because there is so much descriptive work of new species to be undertaken, but because the accomplishment of this work will lead to the solution of problems of migration, and dispersion and of evolution, not only of the older but of the modern types of many of the great biological realms.