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THE DEVELOPMENT OF VERTEBRATE PALAEONTOLOGY IN CHINA DURING THE FIRST HALF OF THE TWENTIETH CENTURY

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This thesis is dedicated,
With respect,
To the living memory
Of
Zhou Mingzhen
(1918 – 1996)

Every landscape appears first of all as a vast chaos, which leaves one free to choose the meaning one wants to give it. But, over and above agricultural considerations, geographical irregularities and the various accidents of history and prehistory, the most majestic meaning of all is surely that which precedes, commands and, to a large extent, explains the others.

Claude Levi-Strauss

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ABSTRACT

This thesis is an account and an analysis of the development of vertebrate paleontology in China during the first half of the twentieth century. This development is grounded in two historic situations: on one hand, the transition, in China, from the dynastic age to the republican age during which a growing interest in Western science and technology led to the development of scientific endeavours and institutions; on the other hand, the importance of the fossil record of China and Central Asia for palaeontologists interested in the evolution of vertebrates.

The multinational exploration of that record is described, with special reference to the work of Pierre Teilhard de Chardin (from France), Johan Gunnar Andersson (from Sweden), the Central Asiatic Expeditions launched by the American Museum of Natural History, and the Sino-Swedish Expeditions (a collaboration between Sven Hedin and Chinese scientists). As a result of the discovery of the site of Peking Man (Zhoukoudian), the Cenozoic Research Laboratory was founded under the joint sponsorship of the Geological Survey of China and the Rockefeller Foundation. The Cenozoic Research Laboratory became the focus of interaction between the Geological Survey of China and the international palaeontological community, and provided an institutional training ground for Chinese vertebrate palaeontologists, who, in turn, were involved in the development, in the early 1950's, of the Institute of Vertebrate Paleontology and Paleoanthropology which grew into the prominent institution we know today.

The development of vertebrate palaeontology in China illuminates the nature of the factors controlling the transfer of scientific disciplines across cultures. Those factors are epistemological and socio-cultural in nature and can be integrated in an explanatory model.

STATEMENT

I, Patricia Komarower, declare that this thesis contains no material which has been accepted for the award of any other degree or diploma in any university or institution.

I affirm that this thesis, to the best of my knowledge, contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Signed: [redacted]

Date: 19/04/2002

ACKNOWLEDGEMENTS

Words fail me in this attempt to express the contribution of my thesis advisor, Patricia Vickers-Rich (School of Geosciences and Monash Science Centre, Monash University). She initiated the project, introduced me to the institutions I relied on for information (the Institute of Vertebrate Paleontology and Paleoanthropology, Beijing, China; the American Museum of Natural History, New York, U.S.A.; the Department of Vertebrate Palaeontology, University of California at Berkeley). Patricia guided and supported the project throughout its long gestation and, in the final stages, provided the mental space, support and trust that I needed to bring it to completion. This project is one of many we have shared, in a long association I treasure: I hope I shall be able to reciprocate in the course of our future projects.

I owe a great debt to Homer Le Grand (Faculty of Arts, Monash University) who made time to introduce me to the field of History and Philosophy of Science and discuss the particulars of the subject of this study.

I benefited greatly from my visits to the Institute of Vertebrate Palaeontology and Paleoanthropology in Beijing and thank the late Zhou Mingzhen, Qiu Zhanxiang, Wang Banyue and Zhang Meeman for their insight into the history and the current practice of vertebrate palaeontology in China.

I wish to express my gratitude for the hospitality and the help I received in the U.S.A. in the course of researching this thesis: from the Library and Department of Vertebrate Palaeontology (especially Dick Tedford) at the American Museum of Natural History; from the Department of Vertebrate Paleontology at the University of California (Berkeley), especially Bill Clemens, with fond memories of my stay in his home.

I warmly acknowledge the help I received from the library of the Museum of Victoria and was very fortunate to have frequent conversations with Tom Rich (Museum of Victoria) about palaeontology and its history, from which I have drawn great pleasure and enlightenment. I look forward to many more...

One of the delights of this thesis has been the opportunity of meeting many people who share my interest in Asia, the evolution of the natural world and the history of its understanding. They are too many to mention but I have especially wonderful memories of long conversations, on several continents, with John Shergold (previously from the Australian Geological Survey Organisation).

I thank the School of Geosciences, the School of Biological Sciences and the Monash Science Centre for providing a stimulating environment for study, work (and play!), and being the meeting place with many friends. This thesis has benefited greatly from the encyclopedic knowledge of Marion Anderson, the editing skills of Mary Walters and the graphic talents of Draga Gelt, and I have benefited from their friendship as well as the friendship and support of many around me: Lesley, Gerry, Jenny, Corrie, Priscilla, Cathy, thank you!

I would also like to thank my yoga teachers, especially Shruti Prakash Guruji, for sharpening my mind and providing yet another way of understanding the world.

Last, but not least, my thanks and love go to my husband, Jean-Loup, and our four-legged companion(s), Maraud.

ADDENDUM

NOTE TO THE READER

This addendum contains corrections to the Ph. D. thesis The Development of Vertebrate Palaeontology in China during the First Half of the Twentieth Century submitted by Patricia Komarower. I, Patricia Komarower, would like to express my gratitude to the examiners for their careful reading of the thesis, highlighting the limitations of the thesis and inspiring new thoughts on further work and post-thesis publication.

All presentation changes (e.g. typographical errors, missing references) have been inserted directly into the corrected text of the thesis (attached as a spiral bound copy for inspection). Corrected tables and maps can also be found in the corrected text of the thesis.

All other changes arising from general or specific comments can be found in this Corrections document which will be bound as an Addendum with the corrected version of the thesis when approval is given.

Changes arising from general comments have been entered as Notes numbered 1, 2, etc. at the beginning of this document. Changes arising from specific comments have been entered as, for example, Notes 1.1, 2.1, 3.1, 4.1 as required where the first digit indicates the thesis chapter relating to the Note and the second digit is a sequential number within the notes relating to a given chapter.

All page numbers and line numbers refer to the corrected version of the thesis.

References within the text of the notes are of two types:

- Author$^{CH.X}$ can be found in the Reference List of the corresponding Chapter X of the thesis.
- Author* can be found in the Reference List at the end of each Corrections document.

When changes are suggested, the original text is provided along with a suggestion for change. The change is indicated in italics within that text, for easier reading.

CORRECTIONS SET 1

GENERAL COMMENTS

NOTE 1

MATERIALS AND METHODS.

Genesis of this study

This study originated from a double source:

1. Professor P. Vickers-Rich, the thesis's main supervisor, had a long-standing interest in the history of paleontology and was particularly interested in documenting the historical background to the foundation of the Institute of Vertebrate Paleontology and Paleoanthropology in the early 1950's
2. The author was also interested in the history and philosophy of palaeontology as well as in the interaction between Chinese culture and western science. This interest developed from the author's cross-cultural background, her interest in languages (especially Mandarin Chinese) and was focused on China as a result of her collaboration with Prof. Vickers-Rich (and other authors) on a Dictionary of Vertebrate Paleontology (Rich *et al.* *, 1994).

This study had a long gestation period during which I (the author) was introduced to the field of history and philosophy of science, thanks to Professor Homer LeGrand, my associate supervisor, and carried out research at the American Museum of Natural History and the Department of Vertebrate Paleontology at the University of California (Berkeley) in 1993. During the course of these visits, I was given access to primary sources such as the diaries of Roy Chapman Andrews, the Correspondence files for the Central Asiatic Expeditions and the Correspondence files for selected individuals of relevance to this study such as P. Teilhard de Chardin, D. Black, O. Zdansky, C.C. Young, J.G. Andersson. I was also able, there, to read Licent's reports (Licent* 1924 & 1935).

I also visited the Institute of Vertebrate Paleontology and Paleoanthropology and the Zhoukoudian Paleoanthropology Research Center in 1994 and 1996 and greatly benefited from extensive conversations (and advice on sources) with the late Zhou Mingzhen (in 1994), and Chinese palaeontologists currently working at the Institute such as Qiu Zhanxiang, Wang Banyue and Zhang Meeman. These two visits were preceded by a three-month stay, in 1986, at the University of Nanjing while working on the dictionary project. During that first visit, I became familiar with the world of universities and palaeontological research in China.

The preceding sources have been very valuable in allowing a gradual understanding of the events studied in this thesis within the specific Chinese circumstances. They have not been specifically quoted in the body of the thesis, as the nature of the information thus gained was either too broad or too specific to have an immediate bearing on the argument.

Scope of the thesis

This thesis, has attempted to paint a picture of the exploration of the fossil vertebrate record of China and Central Asia during the 1920's and 1930's and to understand the nature of the factors bearing on this exploration and its outcome, both for paleontology in general, and for the development of a palaeontological community in China. Each component of this picture could lend itself to a deeper study on its own (and in several cases, has been covered quite extensively by previous authors). The specific aim of this thesis was to weave all these elements together and to highlight their significance from a triple perspective: historical (Chapter 1), palaeontological (Chapters 2 and 3) and philosophical (Chapter 4). Consequently a selection had to be carried out in order to respect the integrity of the original project, and the triple perspective made it imperative to maintain a balance between the levels of detail one could choose to go into. Accordingly, the number of illustrations has been kept to a minimum, focusing on the actors and the geography of the explorations. The interested reader may refer to the publications cited for an illustration of the fossils.

Therefore, many more sources have been consulted than actually quoted; the references quoted in the Reference section of each chapter had an immediate input in the argument of the thesis. Similarly, a choice of events had to be made in order to illustrate particular points. The Levi-Strauss quote in the epigraph was chosen in order to highlight this process.

Previous work

The approach followed in the thesis was inspired by a seminal paper (Mateer & Lucas[CH. 3], 1985), itself an attempt to understand the genesis of the Lagrelius Collection of the Palaeontological Museum at the University of Uppsala (Sweden). That paper was developed by Lucas in the first chapter of a book describing the fossil vertebrate record of China (Lucas[CH. 3], 2001) and given a philosophical framework, using the Basalla three-stage model. In both studies (Lucas, 1985 & 2001), Lucas's understanding has been framed by his initial involvement with the Lagrelius Collection; accordingly, his studies concentrate on the Sino-Swedish program started by J.G. Andersson and underplay other elements such as the Sino-Swedish Expedition led by Sven Hedin, the Central Asiatic Expeditions and the work of E. Licent and P. Teilhard de Chardin. His choice of the Basalla model is quite valid within its limitations (see Chap. 4) as an initial model focusing on the socio-cultural ('externalist') factors. It has been an argument of this thesis that the cognitive ("internalist") elements played a significant part in the development of vertebrate paleontology in China, a part that is not accounted for in the Basalla model.

Similarly, Debaine-Francfort* (1999)'s interesting account has been framed by archaeology, her primary interest, and consequently has underplayed the specifically palaeontological dimension of the events under study in this thesis.

A great number of accounts of the period have also been consulted, focusing on particular aspects; many of those have provided useful background and have not been referenced as they did not have a direct bearing on the argument of the thesis (*e.g.* Lavas*, 1993; Perkins*, 1981; Wallace*, 1994; Preston*, 1988). Other accounts such as Hedin* (1931 & 1991) or published letters such as Teilhard de Chardin* (1962) were very useful.

The preceding list complements the reference lists found in the various chapters of the thesis and at the end of this addendum (which lists all references that have been used in response to the comments of both examiners). Together they represent the sources that have been of most use to the author in this study.

NOTE 2

All of the reference works of direct relevance to this study have been listed in the reference lists, including the Dictionary of National Biography (Gillispie[CH.3], 1970). The Encyclopedia of Paleontology (Singer*, 1999) has also been consulted frequently but has only been cited indirectly (e.g., Boné* (1999), for his biographical sketch and appreciation of Teilhard de Chardin).
Primary sources have been addressed in Note 1.

NOTE 3

All specific stratigraphic terms were defined (in relative terms) in the body of the thesis. A summary of the stratigraphy of the Late Cenozoic of China can be found in Table A1.

NOTE 4

A detailed account of the biostratigraphic outcomes of the discoveries is beyond the scope of the thesis. However, in response to some of the specific points raised by the examiner, the relationship between the development of ideas about the geology of China and the fossil vertebrate record has been analysed in Note 2.2 with specific reference to discovery of Dicynodonts (and the Sino-Swedish Expedition), the Nihewan Fauna (and Teilhard de Chardin) and Zhoukoudian's mammalian discoveries. Note 3.14 further elaborates on mammalian faunas described by Bohlin* (1937a, 1937b, 1942, 1946 & 1951).

NOTE 5

Comparison between the outcomes of the period under examination and the work of subsequent workers is beyond the scope of the thesis; however, it does warrant further examination, which will be carried out in preparation for publication.

SPECIFIC COMMENTS

NOTE 1.1

Self-strengthening quote (p. 1.3). What books were used?

In 1865, the Kiangnan arsenal was established in Shanghai as part of the industrialisation effort during the Self-Strengthening period (1871 – 1896); a translation bureau was attached to the Arsenal. According to Bennett (1967*), a wide variety of books and other publications on science and technology were translated at the Kiangnan Arsenal between 1871 and 1902 by John Fryer and other translators. A total of 329 works had been translated at the Arsenal by 1896 in Military Science (55), Manufacturing (38), Medicine (29), History (25), Mathematics (22), Law (13), Chemistry (12), Physiology (11), Geology, Geography and Astronomy (9), Botany and Zoology (5) and other subjects.

A large number of these translations were published as Handbooks to accompany wall charts or in an Outline Series and are interpreted to be summaries from various sources. Some were translations of monographs such as A Treatise on Meteorological Instruments by E.A.L. Negretti and J.W. Zambra (London, 1864), Sound by J. Tyndall (Longmans, London, 1869), Practical Geometry by W. Burchett (1855), Well's Principles and Applications of Chemistry by D.A. Wells (Ivison, Blakeman, Taylor & Co, New York & Chicago, 1858).

See also Section 1.2.1, in the thesis, on Yen Fu, the scholar-translator.

NOTE 1.2

There is no mention of the Harvard Club in the thesis (See Section 1.2.2 on the Science Society). The subject of the development of western science in Republican China is a vast one and has been covered elsewhere in all its complexity (Buck[CH.1], 1974 and 1980 for example). The purpose of Chapter 1 is to set the scene for the development of one particular discipline, vertebrate palaeontology. Accordingly, representative elements of historical, institutional and scientific interest were selected in order to present aspects of the background to that development.

According to Buck (1980, p.90), there was indeed an effort in Harvard, as well as Cornell, to integrate the Chinese students into the collegial life. The Science Society was highlighted in the thesis for several reasons: its focus on science, its successful transplantation to China in 1914, the fact that both V.K. Ting and Wong Wenhao were among its early members and its role as a forum for Chinese scientists prior to the foundation of Academia Sinica in 1928.

NOTE 1.3

Why Sweden?

Andersson* (1929) relates how, since his appointment as Director of the Geological Survey of Sweden in 1906, he had been involved, with Felix Tegengren, in an inquiry into the iron ore resources of Sweden. When the 11th International Geological Congress met in Stockholm in 1910, he was instrumental in the decision to invite all participating countries to cooperate in "an international inquiry into the iron-ore resources of the world" (Andersson, *ibid.*, p. 11) which resulted in the production of a publication, <u>The Iron-Ore Resources of the World</u>. Another result of this interest was the invitation, along with Tegengren, by the Chinese Government to cooperate with the Geological Survey of China in its investigation of the mineral resources of China (especially iron and coal resources). Andersson and Tegengren were not the first Swedish geologists to work in China: Erik Nystroem had been in China since 1902 where he was associated with the establishment of University of Taiyuanfu (in Shanxi Province) and had established "The Nystroem Institute for Scientific Research in Shansi". Nystroem is credited with establishing the initial cooperation between Chinese and Swedish geologists (Regnell*, 1991).

Leroy* (1971, p. 14), in his introduction to the published letters between Johan Gunnar Andersson and Pierre Teilhard de Chardin highlights the important cultural role played by Sweden in Republican China through its missionaries and scientists.

NOTE 1.4

Max Schlosser and Koken.

The space devoted to Max Schlosser is certainly not proportional to his importance but reflects the linguistic limitations of the author. Schlosser, like Ernst Koken before him, was able to study and describe substantial numbers of Chinese fossil vertebrates collected by others. Koken[CH.1] (1885) described the fossils collected by Ferdinand von Richthofen while Schlosser described a collection of 'dragon bones', which had been purchased in China by K.A. Haberer. Schlosser's study had the bigger impact of the two. Osborn[CH.1] (1910, p. 333) described it as the most exhaustive of all the early studies of fossil vertebrates in China and especially valued in it the comparisons between Miocene and Pliocene life in China, Southern Asia and Europe.

Schlosser was also instrumental in the training of C.C. Young; he was, along with F. Brolli, the supervisor of C.C. Young's Ph. D. program at the University of Munich.

NOTE 2.1

Koken: See Note 1.4

NOTE 2.2

Development of ideas about the geology of China

The stratigraphy of China was established and developed using fossil animals and plants to define intervals of geological time (biochronology) or to define distinctive rock units based on their fossil content (biostratigraphy). Index fossils can be used to assist in palaeoenvironmental, palaeogeographical and palaeoecological reconstruction. Lucas[CH.3] (2001) further distinguishes between biochrons (based on a single taxon) and faunachrons (based on groups of taxa). According to Lucas (*ibid.*, p. 42), China's oldest vertebrates are Early Cambrian agnathans from Yunnan, which were described in 1999 (Shu *et al.**, 1999). Then there is a gap until the Early Silurian, after which the fossil vertebrate record of China figures prominently in constructing the biostratigraphy of China. A detailed study of how this was achieved is beyond the scope of this thesis. Lucas's study (*ibid.*) covers the entire Phanerozoic and makes the importance of the vertebrate fossil discoveries described in this thesis quite clear. Several examples follow, drawn from each of the teams involved in the exploration of the fossil vertebrate record of China at the beginning of the twentieth century.

- Dicynodonts and the Sino-Swedish Expedition

The first Chinese dicynodont from China was collected by Yuan Fu Li in Sinkiang (Xinjiang) in the course of the Sino-Swedish Expedition. It was named *Dicynodon sinkiangensis* and described by Yuan & Young* (1934), later renamed *Jimusaria sinkiangensis* (Sun*, 1973). It was the first evidence in China of what was to become known as the Dicynodon biochron (Lucas, *ibid.*, p. 85) and thus provided added evidence for the cosmopolitanism of this Late Permian genus. This, in turn, was used as an argument for the existence of a single landmass, Pangea by the Late Permian, although recent studies have suggested that there may have been "a clear marine separation of the north China and Kazakhstan blocks from the rest of supercontinent" (Lucas, *ibid.*, p. 87). Lucas goes on to suggest that the home of Chinese Late Permian vertebrates may well have joined Pangea by Late Permian time.

A similar argument applies to the three species of Triassic *Lystrosaurus* discovered during the Sino-Swedish Expedition and described by C.C. Young (1935, 1939): *L. hedini, L. broomi and L. weidenreichi.* The observed overlap between *Dicynodon* (= *Jimusaria*) and Triassic *Lystrosaurus* in the Guodikeng Formation (Junggur Basin, Xinjiang) "raises real questions about the placement of the Permo-Triassic boundary using vertebrate fossils." (Lucas, *ibid.*, p. 91)

- The Nihewan Fauna and Teilhard de Chardin

The Nihewan (Nihowan) Fauna was first described by Teilhard de Chardin & Piveteau[CH.3] (1930) and was assigned a Sanmenian age, transitional between the late Pliocene and the early Pleistocene (see Thesis, section 3.1.3). The Nihewan Fauna is representative of the Early Pleistocene mammalian faunas of northern China (with Palaearctic affinities) and can be correlated with the mammalian faunas of southern China (with Oriental affinities) and the transitional region between the northern and southern regions. The Nihewanian Land-Mammal Age (LMA) is now recognised between the Late Pliocene Youhean LMA and the middle Pleistocene Zhoukoudianan LMA, and ranges between 2.4 Ma and 0.7 MA (Lucas, *ibid.*, p. 264).

- Cretaceous dinosaurs and Mammals, Eocene and Miocene Mammals and the Central Asiatic Expeditions.

The biostratigraphic legacy of the Central Asiatic Expeditions was reviewed in this thesis (p. 3.41). Of particular importance to modern biostratigraphy are:

- the Late Cretaceous dinosaurs and mammals from Nei Mongolia (Inner Mongolia, China) which have formed the basis for the establishment of two land-vertebrate faunachrons: the Baynshirenian (based on the Iren Dabasu locality) and the Djadokhtan (=Djadochtan), based on the Djadochta Formation at Shabarak Usu. These two are the only examples of Late Cretaceous vertebrates in China (Lucas, *ibid.*, p. 194).

- the middle Eocene mammals collected in Irdin Manha (Inner Mongolia, China) were used to establish the Irdinmanhan land-mammal age and correlated with other mammal-bearing localities in other Chinese localities (Lucas, *ibid.*, p. 214).

- the Miocene mammals from Tunggur, also in Nei Mongol (Inner Mongolia, China), including the proboscidean *Platybelodon* (which has become the index taxon of the Tunggurian fauna), are the basis of the Tunggurian middle Miocene age (Lucas, *ibid.*, p. 240)

- Peking Man, Zhoukoudian and Chinese Pleistocene vertebrates

The importance of the discovery of the Zhoukoudian site has been emphasised in the thesis (see Chap. 3, Para 3.6): that discovery has been one of the main factors in the development of vertebrate palaeontology in the region. It remains today one of the main deposits of Pleistocene fishes, reptiles and bird in China and contains a very rich mammalian fauna. The Zhoukoudian site is also one of the main deposits of *Homo erectus* in China, containing more than 40 middle Pleistocene individuals. According to Lucas (*ibid.*, p. 281), the taphonomy of the site has given rise to two interpretations: the traditional view, put forward by Jia Huangpo (Jia & Huang, 1990) and other workers, suggests that the cave site was continually occupied by humans, that the associated vertebrate remains were the product of human hunting and that the humans used tools and fire. The other view, first put forward by Binford & Ho[CH.3] (1985), suggests that most of the vertebrate remains were brought into the cave and that the evidence for burning results from in-situ burning rather than intentional burning by the human occupants.

The preceding review of some important localities discovered during the period studied in the thesis does not attempt to cover the palaeogeographic and palaeoenvironmental implications of these discoveries. The interested reader may wish to refer to Lucas[CH.3] (2001) and the references contained therein.

<u>NOTE 2.3</u>

How actually did Ting die? Immediate repercussions?

Ting died on 5 January 1936, at the age of 48, from the consequences of carbon monoxide inhalation while sleeping in a poorly ventilated room in an inn at Hanyang (Hunan Province) during the night 8-9 December, 1935. He was taken to a local hospital, then to the Hsiang-ya Hospital in Changsha where it is believed his condition became aggravated as a result of poor medical management (Furth[CH.1], 1970; Boorman & Howard[CH.1], 1970).

His death occurred while he was in Hunan, investigating coal resources for the development of the Canton-Hankow railway. This represents the latest stage in an eventful career, the beginnings of which were traced in the thesis (see Chap. 1, Section 1.3.1). As was noted, in 1916, Ting Wenchiang (V.K. Ting) became the Foundation Director of the Geological Survey of China, a position he held until 1921. He resigned his position at the Geological Survey to become the manager of the Pei-piao Coal Mining Company which was founded as a result of a mining survey undertaken by the Geological Survey during Ting's directorship. In the course of his managerial work, he was gradually drawn into political affairs and political journalism while maintaining a lively interest in philosophy. In 1926, he was invited to Shanghai and became involved in the development of a "Greater Shanghai", especially with the management of the port facilities. However, at the end of 1926, he resigned from this position when the Kuomingtang Northern Expedition reached Shanghai and, subsequently, went into a kind of semi-retirement from which he emerged in 1928, when he undertook a comprehensive survey of southwest China for the Geological Survey of China. In 1931, he was appointed Professor of Geology at Peking University and, in 1934, became the Secretary General of Academia Sinica. It was during this period that he undertook the investigation in Hunan during which he died.

NOTE 2.4

Why was Johan Gunnar Andersson invited by the Chinese government? How did the connection between China and Sweden come about?

The circumstances of Andersson's invitation to China have already been sketched in Section 1.3 of the thesis. The wider question of the connection between China and Sweden remains open, although some clues may be found in Leroy's comments about the importance of the Swedish missionary presence in China at he turn of the 20th century (See Note 1.3). A survey of standard histories of the period and region (Fairbank*, 1983; Fairbank & Feuerwerker*, 1986; Spence[CH.1], 1990; Hsu*, 1983) reveals very little specific information about relations between China and Sweden. Further research is needed in order to document the background to what became a very important connection for the history of vertebrate palaeontology.

NOTE 2.5

I was unable to locate the quote alluded to here, and would be grateful to the examiner for further precisions.

NOTES 2.6 & 2.7

Early palaeontological work by the Japanese in China.

The Japanese contribution to the development of vertebrate palaeontology in China is beyond the scope of this thesis, which focuses on the exploration of the fossil vertebrate record of China and Central Asia during the 1920's and 1930's (and could, therefore, be retitled: Aspects of vertebrate palaeontology in China during the first half of the twentieth century). However, it does warrant further research, as Japan was one of the foremost destinations of Chinese students in search of foreign training at the beginning of the twentieth century. Japanese scientists, in turn, undertook geological surveys on Chinese soil, primarily motivated by 'economic' interests (Lee[CH. 1], 1985).

NOTE 2.8

Replace p. 2.6, l. 12:

This resulted in the recognition of the Cambrian, Silurian, Devonian, Carboniferous and Permian periods based on fossil content, and, most importantly, on the recognition that the history of life had been directional and progressive, *from the Silurian with no land plants and no vertebrates to the appearance of fishes during the Devonian, of land plants during the Carboniferous and of reptiles during the Permian.*

With:

This resulted in the recognition of the Cambrian, Silurian, Devonian, Carboniferous and Permian periods based on fossil content, and, most importantly, on the recognition that the history of life had been directional and progressive, *with the appearance of fishes during the Silurian, land plants during the Carboniferous and reptiles during the Permian.*

NOTE 2.9

Insert p.2.8, l. 27:

The work of Edgar Forbes (1815 – 1854), a British botanist and invertebrate palaeontologist, was important in the early stages of biogeography. Forbes studied the changes in molluscan faunas along the British coast as well as in the Aegean Sea (Sarjeant[CH.2], 1980, Vol. 2, p. 1018; Browne[CH.2], 1983) and attempted to correlate the present distribution of floras and faunas in Europe with geological history (Forbes*, 1846).

NOTE 2.10

Replace p. 2.9, l. 24:

Their work was encouraged by Adam Sedgwick and Sir Roderick Murchison, who had embarked on a geological survey of Scotland and *hoped to use* the fossils for dating rocks.

With:

Their work was encouraged by Adam Sedgwick and Sir Roderick Murchison, who had embarked on a geological survey of Scotland and *used* the fossils for dating rocks.

Insert p. 2.10, l. 2:

A detailed account of the role of Scottish workers (and localities), their early work on rhizodont fishes and their relationship to Agassiz is also given in Andrews* (1985).

NOTE 2.11

Replace p. 2.10, l. 9:

His work was inspired by Cuvier's comparative approach.

With:

His work was inspired by Cuvier's comparative approach *and greatly helped by his access to Cuvier's collections. According to Lurie* (1960, p. 57), Cuvier's friendship, in turn, opened up access to other major collections in France.*

Replace p. 2.10, l. 24:

His interests subsequently switched to modern fishes and the study of glaciers.

With:

During the American phase of his career, he concentrated on the study of modern fishes and expanded on the study of glaciers he had started in Switzerland, in the late 1830's.

NOTE 2.12

Replace

Thulborn[CH.2], 1970.

With:

Thulborn & Wade*, 1979.

NOTE 2.13

Insert p. 2.22, l. 23:

Spencer's work was not the last shot in a war of words that saw most of the participants in the Piltdown affair (and others) accused at one time or another. As Stephen Jay Gould put it, in his own argument for Teilhard de Chardin's guilt, "the solution to 'whodunit' becomes 'everybodydunit'" (Gould*, 1983, p. 201). Turritin* (1997), in his annotated bibliography of the Piltdown forgery, has listed 30 different interpretations of the case, published between 1955 and 1996.

NOTE 2.14

Replace p. 2.23, l. 16:

Dart's claim generated a great deal of press coverage, which, along with the lack of availability of casts, may have played a role in the rather reserved reception from the palaeoanthropological establishment of the day (Keith, Smith, Woodward & Duckworth, 1925). When Dart finally came to London with his original material, interest had shifted from the Taung specimen.

With:

Dart's claim generated a great deal of press coverage *(Reader[CH.2], 1981, p. 89)* which, along with the lack of availability of casts, may have played a role in the rather reserved reception from the palaeoanthropological establishment of the day (Keith, Smith, Woodward & Duckworth[CH.2], 1925). When Dart finally came to London with his original material, interest had shifted from the Taung specimen. *According to Tobias* (1985) and Klein* (1989), the coolness of the reaction to the discovery of Australopithecus africanus can be explained by a combination of factors: the African location, the age of the fossil deemed too* *young to be a 'missing link' between ape and man, the anatomy of the skull (characterised by a combination of human teeth with an ape brain) and its association with a bipedal stance, its juvenile character, and finally the personality and age of Dart himself.*

NOTE 2.15

The impact of the discoveries in China and Central Asia on Osborn's and Matthew's understanding of the evolution of Asiatic faunas is beyond the scope of this thesis which addresses the reverse question of the impact of palaeontological thinking at the turn of the twentieth century upon the development of vertebrate palaeontology in China. This question can be extended to all the major participants in the exploration of the Central Asiatic and Chinese vertebrate fossil record: Johan Gunnar Andersson, Teilhard de Chardin, Davidson Black, Walter Granger etc...

No attempt was made in this thesis to analyse this question which could very well be the subject of a separate thesis or of further work arising from this thesis. The interested reader may like to refer to Rainger[CH.3] (1991) and Regal* (2002) on H.F. Osborn, and Colbert* (1992) on W.D. Matthew and the original papers by Osborn and Matthew listed therein, for an assessment of this impact.

NOTE 2.16

Replace p. 2.28, l. 22:

Matthew *was much more tolerant of the continental drift theory in a more or less modified form as a* model for Palaeozoic and Mesozoic geological evolution.

With:

Matthew, *however, accepted that the continental drift hypothesis, with some modification, could provide a satisfactory* model for Palaeozoic and Mesozoic evolution.

Matthew (1939) includes a reprint of Matthew (1915), along with some additional papers and an annotated bibliography, arranged by E.H. Colbert, Matthew's son-in-law and biographer, and a notable palaeontologist himself. The paper quoted from (Matthew, 1939, p.169) is one of the additional papers collected in this Special Publication of the New York Academy of Sciences. It is titled: Note on the Wegener Hypothesis, etc. Supplementary to "Climate and Evolution". According to Note 1 (Matthew, 1939, p. 164):

> The following notes were left in manuscript form at the time of Dr Matthew's death, and were most kindly presented for publication in the present volume by Professor Charles L. Camp of the University of California. Professor Camp makes the following statement with regard to this new contribution: "I have no idea as to when this was written except that it is on a writing pad which was bought in the Orient, so that it must have been during his visit to India. This is all the more likely since he starts the article with some remarks about the East Indies".

NOTE 2.17

No further research was carried out on those "57 individuals whose country of origin could not be ascertained" from sources readily available to the author as it was decided to narrow down the survey to the top 10% of the contributors. Supplementary information regarding Barkas, Fraas, Nehring, and Rivière de Précourt has been included in Table 2.3 (See corrected version of the thesis).

NOTE 3.1

Replace p. 3.1, l. 10

After his arrival in China, he started exploring the Yellow River basin in order to collect geological, zoological and botanical specimens for the Hoangho Paiho Museum he had founded. In the course of these explorations, he had collected mammalian fossils, which he sent to Professor Marcellin Boule at the Paris Museum of Natural History for identification.

With:

Like Teilhard de Chardin, Licent had a passion for natural history and, according to Cuénot (1958), his ambition was to explore the Yellow River Basin systematically and to develop a museum, which would house his collections and make them available to other scientists. He managed to obtain the necessary funds to start building the Hoangho Paiho Museum in Tianjin. The collections of the Hoangho Paiho Museum were subsequently transferred to Peking where they found a home in the Peking Institute of Geobiology established by Teilhard de Chardin in 1940. In the course of his explorations, Licent had collected mammalian fossils, which he sent to Professor Marcellin Boule at the Paris Museum of Natural History for identification.

<u>NOTE 3.2</u>

See corrected Box 3.1 (in corrected version of the thesis).

<u>NOTE 3.3</u>

Insert p. 3.5, l.5

This prediction was indeed validated by later workers. Both faunas are listed as early Oligocene (Shangdolian) by Lucas[CH.3] (2001, pp. 203 and 220).

<u>NOTE 3.4</u>

Replace p. 3.8, l. 25

Breuil described the Mousterian industry and found it to be similar to European types; he recognised the association of the Chinese Mousterian industry with more advanced elements and suggested that Asia might have been a centre of diffusion for this industry.

With:

Breuil described the Mousterian industry and found it to be similar to European types; he recognised the association of the Chinese Mousterian industry with more advanced elements and suggested that Asia might have been a centre of diffusion for this industry. *Henri Breuil (1877-1961), a leading Paleolithic archaeologist, had met Teilhard de Chardin in 1912 at the Museum of Natural History (Paris) and had become his mentor and friend. Two other joint publications between Teilhard de Chardin and Breuil deal with African sites (Teilhard de Chardin, Breuil & Wernert*, 1939-1940; Teilhard de Chardin, Breuil & Wernert*, 1951). Breuil came to inspect the Zhoukoudian site and visit his friend on two instances (1931 and 1935), after he had become Professor of Prehistory at the Collège de France (1929).*

<u>NOTE 3.5</u>

How did Teilhard do his stratigraphy?

The stratigraphic sequence of the localities where Paleolithic artifacts were found was established by correlation with European stages as the fossil remains (mostly mammalian) found in these sediments contain elements that are common to Europe and China, as well as some endemic elements. Boule, in his introduction to their joint publication (Boule, Breuil, Licent & Teilhard[CH.3], 1928), places Teilhard's contribution to the stratigraphy of northern China within a larger undertaking by the Geological Survey of China and J.C. Andersson to try and refine the stratigraphy of what had been mapped as Loess in Richthofen's previous study (Richthofen[CH.1], 1877).

<u>NOTE 3.6</u>

Replace p. 3.16 l. 21:

Teilhard de Chardin left China in 1946 and returned to France where he remained until 1951. During this period, he renewed his contacts with the French scientific community and was elected a member of the Academy of

Science. In 1951, he went to New York where, in spite of failing health, he pursued his palaeoanthropological studies under the patronage of the Wenner-Gren Foundation for Anthropological Research until his death in 1955.

With:

Teilhard de Chardin's return to France was eventually made possible by the end of the Second World War: he arrived in France in May 1946 but had to leave behind most of his books and papers which have since become lost (Cuénot, 1958, p.305). During this period, he renewed his contacts with the French scientific community and was elected a member of the Academy of Science. In 1951, he went to New York where, in spite of failing health *(he had had his first crippling heart attack in 1947),* he pursued his palaeoanthropological studies under the patronage of the Wenner-Gren Foundation for Anthropological Research until his death in 1955.

NOTE 3.7

Insert p. 3.22, l. 34:

...Paleontologia Sinica *(see Section 3.3 for more details on its genesis).*

NOTE 3.8

Replace p. 3.46 l. 9

In spite of some concerns on the part of the College's Director, Dr Henry S. Houghton, Black was able to carry on and develop his own research and, gradually, he established relationships with the growing group of scientists in Peking:

With:

In spite of some concerns *over his focus on anthropology at the expense of anatomy (Hood, 1964, p. 55),* on the part of the College's Director, Dr Henry S.

Houghton, Black was able to carry on and develop his own research and, gradually, he established relationships with the growing group of scientists in Peking:

NOTE 3.9

Davidson Black's empathy with the Chinese (p. 3.46).

The specific reasons for Davidson Black's empathy with the Chinese as recorded in the quote p. 3.46 are in line with his general outlook on human beings generally. There are numerous examples of the perception of Black as "an extraordinarily kind and warm individual" (Shapiro*, 1981, p. 26).

NOTE 3.10

Replace p. 3.47, l. 31:

Black's paper, in which he hails the discovery as a confirmation of the hypothesis put forward in an earlier paper (Black, 1925) that "the great center of dispersal of prosimians, lower catarrhines, anthropoid apes and man must have been located in Asia" (Black, 1925, p. 159), generated much interest and scepticism around the world.

With:

Black's paper, in which he hails the discovery as a confirmation of the hypothesis put forward in an earlier paper (Black, 1925) that "the great center of dispersal of prosimians, lower catarrhines, anthropoid apes and man must have been located in Asia" (Black, 1925, p. 159), generated much interest and scepticism around the world *(Reader[CH.2], 1981, p. 109).*

NOTE 3.11

p. 3.48 Why did Black die?

According to his biographer (Hood[CH.3], 1964, p. 124), Davidson Black had a "transient heart attack" while inspecting the excavation at Zhoukoudian upon his return from his latest overseas trip in 1933. He was subsequently hospitalised for treatment and told of the gravity of his condition. Upon his release from hospital, he starting putting his papers in order, confiding only in his secretary about his health concerns while maintaining his usual routine of working at night.

> On March 15, Davidson Black went to work as usual about five in the afternoon. His friend, C.C. Young, watched him as he walked slowly to his laboratory, clad in his white work coat. "I went to pay him a visit and found him sitting at the desk where he had worked for years and years at science. He talked of his anxiety as to whether his plans for the future of the Cenozoic Research Laboratory could be carried out".
> When his last visitor had left and the quietness of evening had come to the College, Black turned once more to his work. An hour later he was dead (Hood, *ibid.*, p. 125).

A similar picture is painted in Teilhard de Chardin's obituary (Teilhard de Chardin*, 1934):

> Dr Davidson Black died suddenly in his laboratory in Peking on 15 March 1934: he was wearing his work coat and was surrounded by the remains of *Sinanthropus* and some newly discovered skulls from the Upper Paleolithic of Choukoutien (Teilhard de Chardin*, 1934, p. 424, trans. by the author).

p. 3.49 Reference for the name *H. erectus pekinensis*?

Replace p. 3.49 l. 6:

On the basis of this tooth, Black established a new hominid genus and species: *Sinanthropus pekinensis* Black & Zdansky (which was dubbed 'Peking Man' by Grabau).

With:

On the basis of this tooth, Black* *(1927)* established a new hominid genus and species: *Sinanthropus pekinensis* Black & Zdansky (which was dubbed 'Peking Man' by Grabau).

According to Klein[CH.3] (1989), the renaming of *Sinanthropus pekinensis* as *Homo erectus pekinensis* occurred as a result of the observation by Mayr* (1950) that the differences between *Sinanthropus pekinensis* and *Pithecanthropus erectus* (Java Man) did not warrant the existence of separate genera.

Later, Le Gros Clark* (1955) suggested that *Sinanthropus* be placed within *Pithecanthropus*; in 1964, Le Gros Clark* (1964) observed that the similarities between *Pithecanthropus* and *Homo* were sufficient to warrant for *Pithecanthropus* to be placed within *Homo*. In his review of *Homo erectus,* Howells* (1966) describes how, according to the rules of the International Commission on Zoological Nomenclature, *Pithecanthropus* retained its species name and became *Homo erectus* (Dubois, 1894), while *Sinanthropus pekinensis*, considered the "junior name", preserved its species name as a subspecies name and became *Homo erectus pekinensis* (Black & Zdansky, 1927). Many hominid fossils have since been attributed to *Homo erectus*, found in Africa, East Asia and possibly Europe.

NOTE 3.12

According to Sun & Zhou[CH.3] (1991, p. 113), C.C. Young returned to China in 1928 and started work at the Geological Survey of China. The publication of Young's doctoral thesis (Young, 1927) "represents the first professional paper of vertebrate paleontology written by a Chinese" (Sun & Zhou, *ibid.*). No information about C.C. Young's time in Germany was available to the author.

NOTE 3.13

The debate surrounding the relationship between *Sinanthropus* and *Pithecanthropus* is beyond the scope of the thesis, which did not address this level of taxonomic details. It will be included in post-thesis publications.

NOTE 3.14

Comments on the Sino-Swedish Expeditions publications on Vertebrate Paleontology

5 publications listed in Table 3.1

1. Bohlin* (1937a). Eine Tertiäre Säugetier-Fauna aus Tsaidam (Tertiary Mammal Fauna from Tsaidam.

This Tertiary fauna from Tsaidam (Qaidam, western Gansu) is the oldest *Hipparion*-bearing fauna in China and also comprises some Carnivora, Proboscidea, Cervidae (including a new species *Lagomeryx tsaidamensis*), Bovidae (including the new genera and species *Olonbulukia tsaidamensis*, *Qurliqnoria cheni* and *Tossunoria pseudibex* as well as the newly described *Tsaidomotherium hedini* Bohlin 1935), Giraffidae, Rhinocerotidae (including the new species *Dicerotherium tsaidamense*).

According to Lucas[CH.3] (2001, p. 242), the Tsaidam fauna is thus the oldest of the Bahean Land Mammal Age (Late Miocene) which begins with the appearance of *Hipparion* in China and shows a mixture of survivors of the preceding Tungurian Land Mammal Age, mammals characteristic of the Bahean Land Mammal Age and some unique taxa (the Bovidae).

2. Bohlin* (1937b). Oberoligozäne Saugetiere aus dem Shargeiltein-Tal (western Kansu)
3. Bohlin* (1942). The fossil mammals from the Tertiary deposit of Taben-buluk, Western Kansu - Insectivora and Lagomorpha
4. Bohlin* (1946). The fossil mammals from the Tertiary deposit of Taben-buluk, western Kansu – Simplicidentata, Carnivora, Artiodactyla, Perissodactyla and Primates

These three publications have been grouped together as they all deal with Late Oligocene localities from western Gansu: Shargaltein Gol and Taben Buluk. The Shargaltein Gol fauna comprises mostly Rodentia (Duplicidentata such as *Desmatolagus* and the new genus *Sinolagomys*, and Simplicidentata).

The Taben-buluk fauna content is listed in the titles: the most noteworthy elements of this fauna, according to Bohlin* (1942), are the new genus *Sinolagomys* and the presence of a primate jaw fragment and possible tooth. Bohlin (*ibid.*) notes the similarity between the Taben-buluk fauna, the Hsanda-gol fauna from Mongolia collected and described by the Central Asiatic Expedition (Matthew & Granger*, 1924), and the Saint Jacques fauna (Ordos Basin) described by Teilhard de Chardin[CH.3] (1926a).
According to Lucas (2001, p. 222), the Taben-buluk fauna, however, is slightly younger (Late Oligocene) than either the Hsanda-gol or the Saint-Jacques fauna which are Early Oligocene in age. The Taben-buluk fauna first described by Bohlin (1942, 1946) is the basis for the establishment of the Taben-bulukian Land Mammal Age (Lucas, *ibid.*).

5. Bohlin* (1951). Some mammalian remains from Shih-her-ma-ch'eng, Hui-hui-p'u area, Western Kansu.

The highlight of the mammalian assemblage in this locality is a new genus and species, *Mimolagus rodens*, which was attributed to the Duplicidentata (lagomorphs). This assemblage was estimated to be from the earlier part of the Tertiary but could not be dated more precisely.
According to Lucas (2001), the relationship of lagomorphs to rodents has long been a disputed question and it is only recently that the Glires (including rodents and lagomorphs) have been divided into Simplicidentata (rodents and mixodonts) and Duplicidentata (lagomorphs).
The importance of *Mimolagus* is highlighted by Carroll* (1988) who describes it as one of the most primitive of the lagomorphs and may indeed belong to the group which is ancestral to both rodents and lagomorphs, the order Anagalida which originated in Asia.

6. Bohlin* (1953). Fossil Reptiles from Mongolia and Kansu.
This paper describes a variety of Archosauria (mostly Dinosauria) and Chelonia collected by the Sino-Swedish Expedition in several Mesozoic localities of Mongolia and Gansu. The Archosauria assemblage is similar to that collected by the Central Asiatic Expedition (with *Protoceratops*, *Velociraptor* and possible

Psittacosaurus species) but much poorer in quality. The Chelonia assemblage contains several new genera: *Peishanemys*, *Tsaotanemys* and *Yumenemys*. *Peishanemys* is of particular importance as it is one of the key taxa for the Khukhtekian (Early Cretaceous) land-vertebrate age, along with *Psittacosaurus* and the mammal *Gobiconodon* (Lucas, 2001, p. 170).

NOTE 3.15

Teilhard de Chardin at the turn of the 21st century.

The appreciation of Teilhard de Chardin as a palaeontologist and of his contribution to vertebrate palaeontology has been in inverse proportion to his growing posthumous influence as a philosopher, theologian and mystic based on a large collection of works published after his death (the most important of which is probably The Phenomenon of Man) in which Teilhard de Chardin developed his "synthesis of a distinctly Christian evolutionary theory" (Boné*, 1999). Accordingly, Boné devotes only one paragraph to Teilhard de Chardin's work on the stratigraphy and palaeontology, which "added substantially to the knowledge of sedimentary deposits and the history of life in Asia (particularly the history of Cenozoic mammals and human evolution)" (Boné, *ibid.*, p. 1225). Teilhard de Chardin's "Christian evolutionary synthesis" squarely belongs to the tradition of natural philosophy, characterised by a search for the meaning and place of human beings in the universe. This theme has been explored by Gould* (1983) in his essay Our Natural Place where Teilhard de Chardin is placed at the anthropocentric end of a spectrum whose zoocentric end is represented by the sociobiological research programme (Wilson*, 1975). In this essay, Gould makes the interesting observation that "Teilhard used the term evolution in a metaphysical sense to identify the laws of cosmic progress, not in our usual sense to specify the mechanics of organic change (which Teilhard recognized and studied, but called *transformisme*)" (Gould, *ibid.*, p. 249). According to Laurent* (1995), Teilhard de Chardin's *transformisme*, which informs his palaeontological work, can be traced directly to Albert Gaudry (Marcellin Boule 's predecessor in the Chair of Palaeontology at the Museum of Natural History in Paris), whom Laurent calls the "spiritual father" of Teilhard de

Table A.1 – Late Cainozoic stratigraphy of North China

	LATE CAINOZOIC STRATIGRAPHY OF NORTH CHINA (Teilhard de Chardin & Licent [CH.3], 1924; Licent & Teilhard de Chardin[CH.3], 1925; Teilhard de Chardin & Young[CH.3], 1933; Teilhard *de Chardin**, *1937*	LATE CAINOZOIC STRATIGRAPHY OF NORTH CHINA (Meyerhoff *et al.**, 1991)	LAND MAMMAL AGES OF CHINA (Lucas[CH.3], 2001)	EUROPEAN STAGES (Meyerhoff *et al.**, 1991)
HOLOCENE		Brown-Yellow & Black soils		
UPPER/LATE PLEISTOCENE	Neolithic Black	- Glacial deposits and soils - Loess & soil deposits - Glacial deposits & yellow-brown soils	SALAWUSUAN	Wurmian Riss-Wurmian
MIDDLE PLEISTOCENE	Paleolithic Yellow Earths	-Reddish clays -Glacial deposits with brown clays	ZHOUKOUDIANAN	Rissian Mindel-Rissian Mindelian
LOWER/EARLY PLEISTOCENE		-Lacustrine clays -Glacial deposits -Lacustrine/fluvial clays/sands	NIHEWANIAN	Gunz-Mindelian **Villafranchian** Gunzian
UPPER/LATE PLIOCENE	Sanmenian Reddish clays		YOUHEAN	Astian Plaisancian Pontian
LOWER/EARLY PLIOCENE	Pontian Red Earths With *Hipparion richthofeni*		JINGLEAN	
UPPER/LATE MIOCENE		Yellow/gray mudstones/sandstones	BAODEAN BAHEAN	Sarmatian Vindobonian

Late Cainozoic stratigraphy of North China

REFERENCES

ANDERSSON, J.G., 1929. The origin and aims of the Museum of Far Eastern Antiquities. *Bulletin of the Museum of Far Eastern Antiquities (Stockholm)* 1, pp. 11 – 27.

ANDREWS, S.M., 1985. Rhizodont crossopterygian fish from the Dinantian of Foulden, Berwickshire, Scotland, with a re-evaluation of this group. *Transactions of the Royal Society of Edinburgh: Earth Sciences* 76, pp. 67 – 95.

BEARD, K.C. & DAWSON, M.R., 1998. The dawn of the age of mammals in Asia. *Bulletin of Carnegie Museum of Natural History* 34.

BENNETT, A. A., 1967. *John Fryer: The introduction of Eastern Science and Technology into Nineteenth-Century China.* Harvard East Asian Monographs No 24, Harvard University Press, Cambridge, Mass.

BLACK, D. 1927. On a lower molar hominid tooth from the Chou Kou Tien deposit. *Paleontologia Sinica,* Series D, 7(1).

BOHLIN, B., 1937a. Eine Tertiäre Säugetier-Fauna aus Tsaidam. *Reports from the Scientific Expedition to the north-western Provinces of China under the leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 1.

BOHLIN, B.,1937b. Oberoligozäne Saugetiere aus dem Shargeiltein-Tal (western Kansu). *Reports from the Scientific Expedition to the north-western Provinces of China under the leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 5.

BOHLIN, B., 1942. The fossil mammals from the Tertiary deposit of Taben-buluk, Western Kansu - Insectivora and Lagomorpha. *Reports from the Scientific Expedition to the north-western Provinces of China under the leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 20.

BOHLIN, B., 1946. The fossil mammals from the Tertiary deposit of Taben-buluk, western Kansu – Simplicidentata, Carnivora, Artiodactyla, Perissodactyla and Primates. *Reports from the Scientific Expedition to the north-western Provinces of China under the leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 28.

BOHLIN, B., 1951. Some mammalian remains from Shih-her-ma-ch'eng, Hui-hui-p'u area, Western Kansu. *Reports from the Scientific Expedition to the north-western Provinces of China under the leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 35.

BOHLIN, B., 1953. Fossil Reptiles from Mongolia and Kansu. *Reports from the Scientific Expedition to the north-western Provinces of China under the leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 37.

BONE, E.L., 1999. Teilhard de Chardin, Pierre. *In* SINGER, R. (Ed.). *Encyclopedia of Paleontology.* Fitzroy Dearborn Publishers, Chicago, pp. 1225 – 1226.

BRANAGAN, D.F., 1997. Robert Logan Jack, Geologist in China. *Proceedings of the 30th International Geological Congress* 26, pp. 177 – 186.

CARROLL, R.L., 1988. *Vertebrate Paleontology and Evolution.* Freeman and Co, New York.

COLBERT, E.H., 1992. *William Diller Matthew Paleontologist – The Splendid Drama Observed.* Columbia University Press.

DEBAINE-FRANCFORT, C., 1999. *The Search for Ancient China.* Thames & Hudson.

FAIRBANK, J.K., Ed., 1983. *The Cambridge History of China, Vol. 12, Republican China 1912 –1949, Part 1.* Cambridge University Press.

FAIRBANK, J.K. & FEUERWERKER, A., Eds, 1986. *The Cambridge History of China, Vol. 13, Republican China 1912 –1949, Part 2.* Cambridge University Press.

FORBES, E., 1846. On the connexion between the distribution of the existing fauna and flora of the British Isles, and the geological changes which have affected their area, especially during the epoch of the northern drift. *Memoirs of the Geological Survey of Great Britain* 1, pp. 336 – 432.

GAUDRY, A., 1872. Sur des ossements d'animaux quaternaires que M. l'abbé David a recueillis en Chine. *Bulletin de la Société Géologique de France* XXIX (2), pp. 177-179.

GOLDBERG, P., WEINER, S. *et al.*, 2001. Site formation processes at Zhoukoudian, China. *Journal of Human Evolution* 41, pp. 483 – 530.

GOULD, S.J., 1983. *Hen's Teeth and Horse's Toes.* W.W. Norton, New York. Pp. 201 – 226.

GREGORY, W.K., 1949. Franz Weidenreich, 1873 – 1948. *American Anthropologist* 51, pp. 85 –90.

HEDIN, S., 1931. *Across the Gobi Desert.* Routledge & Sons, 1931.

HEDIN, S., 1991. *My Life as an explorer.* Oxford University Press.

HOWELLS, W.W., 1966. *Homo erectus. Scientific American* 215(5), pp. 46 – 53.

KLEIN, R.G., 1989. *The Human Career – Human Biological and Cultural Origins.* University of Chicago Press.

LAURENT, G., 1995. Paléontologie et évolution chez Teilhard de Chardin. *Mémoires de la Société géologique de France* 168, pp. 97 – 100.

LAVAS, J.R., 1993. *Dragons from the Dunes – The Search for Dinosaurs in the Gobi Desert.* Published by the author, P.O. Box 14-421, Panmure, Auckland.

LE GROS CLARK, W.E., 1955. *The fossil evidence for human evolution.* 1st ed., University of Chicago Press.

LE GROS CLARK, W.E., 1964. *The fossil evidence for human evolution.* 2nd ed., University of Chicago Press.

LEROY, P., 1971. *Dans le Sillage des Sinanthropes – Lettres Inédites de Pierre Teilhard de Chardin et Johan Gunnar Andersson 1926 – 1934.* Fayard.

LICENT, E., 1924. *Compte-Rendus de Dix Années de Séjour et d'Exploration dans le Bassin du Fleuve Jaune, du Pai Ho et des autres Tributaires du Golfe de Pei Tcheu Ly.* Librairie Française, Tientsin.

LICENT, E., 1935. *Compte-Rendus de 11 Années (1923-1933) de Séjour et d'Exploration dans le Bassin du Fleuve Jaune, du Pai Ho et des autres Tributaires du Golfe de Pei Tcheu Ly.* Mission de Sienhsien, Race Course Rd, Tientsin.

LICENT, E. & TRASSAERT, M. 1935. The Pliocene lacustrine series in central Shansi. Bulletin of the Geological of China 14, pp. 211-219.

LIU, D.S. & Lu, Y.C., 1991. P. Teilhard de Chardin's contributions to the scientific exchanges between China and the West. *In* WANG, H.Z., YANG, G.R. & YANG, J.Y. (Eds). *Interchange of Geoscience Ideas between the East ad the West.* Proceedings of the XVth International Symposium of INHIGEO, October 25 – 31, 1990, Beijing. China University of Geosciences Press.

LUCAS, S., 2002. Walter Granger, 1872 – 1941, Paleontologist. *New Mexico Museum of Natural History and Science Bulletin* 19, 58 pp.

MATTHEW, W.D & GRANGER, 1924. New Carnivora from he Tertiary of Mongolia. *American Museum Novitates* 97.

MAYR, E., 1950. Taxonomic categories in fossil hominids. *Cold Spring Harbor Symposia on Quantitative Biology* 15, pp. 109 – 118.

MEYERHOFF, A.A., KAMEN-KAYE, M., CHEN, C. & TANER, I., 1991. *China – Stratigraphy, Paleogeography and Tectonics.* Kluwer Academic Publishers, Dordrecht.

MORTILLET, G. de, 1883. *Le Préhistorique.* Paris.

OSBORN, H.F., 1903. The reptilian subclasses Diapsida and Synapsida and the early history of the Diaptosauria. *Memoirs of the American Museum of Natural History* 1.

PERKINS, J., 1981. *To the ends of the Earth – Four Expeditions to the Arctic, the Congo, the Gobi, and Siberia.* Pantheon Books, New York.

PRESTON, D.J., 1988. *Dinosaurs in the Attic – An Excursion into the American Museum of Natural History.* Ballantine Books, New York.

REGAL, B., 2002. *Henry Fairfield Osborn - Race and the Search for the Origins of Man.* Ashgate Publishing Co.

REGNELL, G., 1991. Swedish Geologists in China. In WANG, H.Z., YANG., G.R. & YANG, J.Y. (Eds). *Interchange of Geoscience Ideas between the East and the West.* Proceedings of the XVth International Symposium of INHIGEO October 25 – 31, 1990, Beijing.

RICH, P.V., ZHANG, Y.P., CHOW, M.C., WANG, B.Y., KOMAROWER, P., FAN, J.H., SLOSS, R., MOODY, J.K.M. & DAWSON, J., 1994. *A Chinese – English and English – Chinese Dictionary of Vertebrate Paleontology Terms.* Monash University, Melbourne.

SHAPIRO, H.L., 1981. Davidson Black: An appreciation. *In* SIGMOND, B.A. & CYBULSKI, J.S., Eds. *Homo erectus – Papers in Honor of Davidson Black.* University of Toronto Press, pp. 21 - 26.

SHU, D., LUO, H., CONWAY MORRIS, S., HANG, X., HU, S., CHEN, L., HAN, J., HU, M., LI, Y. & CHEN, L., 1999. Lower Cambrian vertebrates from south China. *Nature* 402, pp. 42 - 46.

SINGER, R. (Ed.). *Encyclopedia of Paleontology.* Fitzroy Dearborn Publishers, Chicago.

SUN, A., 1973. A new Species of *Dicynodon* from Sinkiang. *Vertebrata PalAsiatica* 11, pp. 52 – 58.

TEILHARD DE CHARDIN, P., 1934. Nécrologie – Davidson Black. *L'Anthropologie* XLIV, pp. 424 – 426.

TEILHARD DE CHARDIN, P., 1937. The Pleistocene of China – Stratigraphy and correlations. *L'Anthropologie* 47, pp. 211 – 220.

TEILHARD DE CHARDIN, P., 1956. *Letters from a Traveller.* Fontana Books.

TEILHARD DE CHARDIN, P., BREUIL, H. & WERNERT, P., 1939 – 1940. Les industries lithiques de Somalie Française. *L'Anthropologie* XLIX(1939-1940), pp. 497 – 522.

TEILHARD DE CHARDIN, P., BREUIL, H. & WERNERT, P., 1951. Le Paléolithique du Harrar. *L'Anthropologie* XLIX(1951), pp. 219 – 230.

TEILHARD DE CHARDIN, P. & PIVETEAU, J., 1930. Les mammifères fossiles de Nihowan (Chine). *Annales de Paléontologie* XIX, pp. 1 – 134.

TEILHARD DE CHARDIN, P., YOUNG, C.C., PEI, W.C. & CHANG, H.C. (1935): On the Cenozoic formations of Kwangsi and Kwangtung. Bulletin of the Geological Society of China XIV, pp. 179 – 210.

THULBORN, R.A & WADE, M., 1979. Dinosaur stampede in the Cretaceous of Queensland. *Lethaia* 12, pp. 275 – 279.

TOBIAS, P.V., 1985. The former Taung Cave system in light of contemporary report and its bearing on the skull's provenance: early deterrents to the acceptance of *Australopithecus. In* Tobias, P.V., Ed. *Hominid Evolution: Past, Present and Future*, Alan R. Liss, New York, pp. 25 –40.

TURRITIN, T., 1997. *A Mostly Complete Piltdown Man Bibliography.*
Available:
http://www.talkorigins.org/faqs/piltdown/piltref.html
Accessed: 5 February 2003.

WALLACE, J., 1994. *The American Museum of Natural History's Book of Dinosaurs and Other Ancient Creatures.* Simon & Schuster, Australia.

WILSON, E.O., 1975. *Sociobiology: The New Synthesis.* Harvard University Press, Cambridge, Mass..

YOUNG, C.C., 1935. On two skeletons of Dicynodontia. *Bulletin of the Geological Society of China* 14, pp. 483 – 517.

YOUNG, C.C., 1939. Additional Dicynodontia remains from Sinkiang. *Bulletin of the Geological Society of China* 19, pp. 111 – 136.

YUAN, P.L. & YOUNG, C.C., 1934. On the discovery of a new dicynodon in Sinkiang: *Bulletin of the Geological Society of China* 13, pp. 563 – 574.

CORRECTIONS SET 2

GENERAL COMMENTS

NOTE 1

MATERIALS AND METHODS.

Genesis of this study

This study originated from a double source:

1. Professor P. Vickers-Rich, the thesis's main supervisor, had a long-standing interest in the history of paleontology and was particularly interested in documenting the historical background to the foundation of the Institute of Vertebrate Paleontology and Paleoanthropology in the early 1950's
2. The author was also interested in the history and philosophy of palaeontology as well as in the interaction between Chinese culture and western science. This interest developed from the author's cross-cultural background, her interest in languages (especially Mandarin Chinese) and was focused on China as a result of her collaboration with Prof. Vickers-Rich (and other authors) on a Dictionary of Vertebrate Paleontology (Rich *et al.* *, 1994).

This study had a long gestation period during which I (the author) was introduced to the field of history and philosophy of science, thanks to Professor Homer LeGrand, my associate supervisor, and carried out research at the American Museum of Natural History and the Department of Vertebrate Paleontology at the University of California (Berkeley) in 1993. During the course of these visits, I was given access to primary sources such as the diaries of Roy Chapman Andrews, the Correspondence files for the Central Asiatic Expeditions and the Correspondence files for selected individuals of relevance to this study such as P. Teilhard de Chardin, D. Black, O. Zdansky, C.C. Young, J.G. Andersson. I was also able, there, to read Licent's reports (Licent* 1924 & 1935).

I also visited the Institute of Vertebrate Paleontology and Paleoanthropology and the Zhoukoudian Paleoanthropology Research Center in 1994 and 1996 and greatly benefited from extensive conversations (and advice on sources) with the late Zhou Mingzhen (in 1994), and Chinese palaeontologists currently working at the Institute such as Qiu Zhanxiang, Wang Banyue and Zhang Meeman. These two visits were preceded by a three-month stay, in 1986, at the University of Nanjing while working on the dictionary project. During that first visit, I became familiar with the world of universities and palaeontological research in China.

The preceding sources have been very valuable in allowing a gradual understanding of the events studied in this thesis within the specific Chinese circumstances. They have not been specifically quoted in the body of the thesis, as the nature of the information thus gained was either too broad or too specific to have an immediate bearing on the argument.

Scope of the thesis

This thesis, has attempted to paint a picture of the exploration of the fossil vertebrate record of China and Central Asia during the 1920's and 1930's and to understand the nature of the factors bearing on this exploration and its outcome, both for paleontology in general, and for the development of a palaeontological community in China. Each component of this picture could lend itself to a deeper study on its own (and in several cases, has been covered quite extensively by previous authors). The specific aim of this thesis was to weave all these elements together and to highlight their significance from a triple perspective: historical (Chapter 1), palaeontological (Chapters 2 and 3) and philosophical (Chapter 4). Consequently a selection had to be carried out in order to respect the integrity of the original project, and the triple perspective made it imperative to maintain a balance between the levels of detail one could choose to go into. Accordingly, the number of illustrations has been kept to a minimum, focusing on the actors and the geography of the explorations. The interested reader may refer to the publications cited for an illustration of the fossils.

Therefore, many more sources have been consulted than actually quoted; the references quoted in the Reference section of each chapter had an immediate input in the argument of the thesis. Similarly, a choice of events had to be made in order to illustrate particular points. The Levi-Strauss quote in the epigraph was chosen in order to highlight this process.

Previous work

The approach followed in the thesis was inspired by a seminal paper (Mateer & Lucas[CH. 3], 1985), itself an attempt to understand the genesis of the Lagrelius Collection of the Palaeontological Museum at the University of Uppsala (Sweden). That paper was developed by Lucas in the first chapter of a book describing the fossil vertebrate record of China (Lucas[CH. 3], 2001) and given a philosophical framework, using the Basalla three-stage model. In both studies (Lucas, 1985 & 2001), Lucas's understanding has been framed by his initial involvement with the Lagrelius Collection; accordingly, his studies concentrate on the Sino-Swedish program started by J.G. Andersson and underplay other elements such as the Sino-Swedish Expedition led by Sven Hedin, the Central Asiatic Expeditions and the work of E. Licent and P. Teilhard de Chardin. His choice of the Basalla model is quite valid within its limitations (see Chap. 4) as an initial model focusing on the socio-cultural ('externalist') factors. It has been an argument of this thesis that the cognitive ("internalist") elements played a significant part in the development of vertebrate paleontology in China, a part that is not accounted for in the Basalla model.

Similarly, Debaine-Francfort* (1999)'s interesting account has been framed by archaeology, her primary interest, and consequently has underplayed the specifically palaeontological dimension of the events under study in this thesis.

A great number of accounts of the period have also been consulted, focusing on particular aspects; many of those have provided useful background and have not been referenced as they did not have a direct bearing on the argument of the thesis (*e.g.* Lavas*, 1993; Perkins*, 1981; Wallace*, 1994;

Preston*, 1988). Other accounts such as Hedin* (1931 & 1991) or published letters such as Teilhard de Chardin* (1967) were very useful.

The preceding list complements the reference lists found in the various chapters of the thesis and at the end of this addendum (which lists all references that have been used in response to the comments of both examiners). Together they represent the sources that have been of most use to the author in this study.

NOTE 2

Summary of important palaeontological discoveries in China and Central Asia during the 1920's and the 1930's

See Table A – 1

NOTE 3

The stratigraphic significance of *Hipparion richthofeni* is illustrated in Table A-2 which summarises the Late Cainozoic stratigraphy of China.

NOTE 4

The relevance of the Central Asiatic fossil vertebrate record for mammalian evolution is spelt out in Note 3.13.

NOTE 5

See Table A-2 which summarises the Late Cainozoic stratigraphy of China, and highlights the transitional nature of the Nihowan fauna.

NOTE 6

All maps have been amended according to suggestions; the names of important localities have been highlighted. See Figs 3.2, 3.3, 3.8, 3.10 in thesis.

NOTE 7

Latour & Polanco rose-window circle - The fourth circle: Representation (p. 4.6, l. 19)

A survey of the relevant literature produced for the general public shows that a great number of the scientists involved in the exploration of the fossil vertebrate record of China and Central Asia were interested in communicating the progress of their exploration and their results to a larger audience. They include:

1. Roy Chapman ANDREWS, the author of The New Conquest of Central Asia (1932) and of many popular books such as:

Across Mongolian Plains, 1921

On the trail of Ancient Man, 1926

Ends of the Earth, 1929.

Andrews also wrote a large number of articles in general publications such as:

- *Harper's Magazine* (*e.g.*: The Frontier of the Forbidden Land, Vol. 136 (816), 1918; Hunting the Great Ram of Mongolia, Vol. 142(4), 1920 and others) *National Geographic Magazine* (*e.g.*: Exploring Unknown corners of the Hermit Kingdom, Vol. 36 (1), 1919; Explorations in the Gobi Desert, Vol. 63(6), 1933 and others).
- *Asia*, published by the American Asiatic Society (A New Search for the Oldest Man: A Great American Expedition to Asia, Vol. 20(10), 1920; The crowning discovery in the Gobi, Vol. 26(4), 1926 and others).
- *Natural History* published by the American Museum of Natural History (New Expeditions to Central Asia: To the Earth's most ancient center of human dispersal, Vol. 20(4), 1920; The Mongolian Wild Ass 33(1), 1933, and others).
- *Saturday Evening Post* (Gobi Bound, Nov.3, 1923; Eggs at 60,000 a Dozen, May 24, 1924 and others).

The American Museum of Natural History was, of course, the major sponsor of the Central Asiatic Expeditions, while the American Asiatic Society provided substantial funds. The other publications were certainly, albeit in ways that are difficult to evaluate, instrumental in raising interest and encouraging more than 383 individuals to provide funds for the Central Asiatic Expeditions.

2. Walter GRANGER:

- *Natural History*: Camp Life in the Gobi Desert (Vol. 31, pp. 359 – 373, 1931); The story of the dinosaur eggs (Vol. 38, pp. 21 – 25, 1936); with W.D. Matthew: Important Results of the Central Asiatic Expedition: the most Significant Fossil Finds of the Mongolian Expedition (Vol. 26(5), pp. 532 – 534, 1926).

3. Henry Fairfield OSBORN:

- *Asia*: Proving China the Mother of the Continents (Vol. 22, pp. 721 – 724, 1922) and others.

4. Pierre TEILHARD DE CHARDIN wrote a number of articles on his palaeontological work in religious publications such as:

- *The Irish Ecclesiastical Record* (The Paleontology of Mammifers in China, Vol. 36, pp. 363 – 369, 1930) and in more general publications such as
- *The Living Age* (Fossil Man, Vol.230, pp. 415 – 419, Boston, 1922),
- *Natural History* (Fossil Man in China and Mongolia, Vol. 26) and others.

5. Sven HEDIN followed the long-established tradition of travellers-naturalists and dedicated much of his time writing books narrating his travels, which, in turn, established his name in wider circles and allowed him to gather funds. Among his many books, his narrative of the Sino-Swedish Expeditions figures prominently (see Hedin & Bergman143a, 1943b and 1944). There are many others, among which Across the Gobi Desert (Routledge & Sons, 1931), Jehol, City of Emperors (Kegan Paul, Trench, Trubner & Co, 1932), The Wandering Lake (Routledge & Sons, 1940).

6. Similarly, Johan Gunnar ANDERSSON and his work in China reached the general public through the publication of many popular books, one of which, Children of the Yellow Earth (1934), was widely read in its English translation.

NOTE 8

All suggestions for the presentation have been implemented in the corrected version of the thesis.

SPECIFIC COMMENTS

NOTE 2.1

Replace p. 2.1, l. 4:

During the same period, a cognitive shift was taking place, according to Laudan (1984, p. 55), away from the view that "we should seek to restrict our theories entirely to claims about observable entities and processes"

With:

During the same period, a cognitive shift was taking place, according to Laudan (1984, p.55), away from the view that "we should seek to restrict our theories entirely to claims about observable entities and processes" *towards "the legitimacy of postulating unseen entities".*

NOTE 2.2

W.D. Matthew has indeed published a large number of papers between 1880 and 1920: 220 papers are recorded in Colbert* (1992) including some co-authored with Walter Granger. Granger is also under-reported because of the predominantly American focus of his early work: 24 papers were published prior to 1920 (Lucas*, 2002). The under-reporting of these two eminent paleontologists results from the bias inherent in the sources used (Romer *et al.*[CH.2]), which focuses on non-American material. This bias was made quite clear in the body of the thesis (Chap.2, Para. 2.2).

There are limitations to the approach I have selected, which will be remedied, for publication, by including all references dealing with American fossils (Hay[CH.2], 1902 & 1929). The choice of the number of publications is also problematic as was pointed out by one of the thesis examiners: Thomas Palliser Barkas is included in the final selection including the top 10% of the contributors, on account more of his prolific output than of his eminence. Romer *et al.* (*ibid.*) struggled with this issue (see quote in Chap. 2, Para. 2.2).

NOTE 2.3

Replace p. 2.5, l. 16:

1830 - 1850: From Lyell to Darwin

With

1820 - 1850: From Lyell to Darwin

Note: 1830 had been highlighted as the date of publication of Principles of Geology.

NOTE 2.4

Insert p. 2.8, l. 7:

Gaudry, a little later, also studied some of the fossil material found by Père Armand David in China (Gaudry*, 1872).

NOTE 2.5

Replace p. 2.12, l. 11:

According to J. Piveteau (1955), subsequent studies by R. Owen, E.D. Cope, H.G. Seeley and T.H. Huxley led to establishment by H.F. Osborn in 1903 of two major divisions according to the structure of the temporal region: the Synapsida (one single temporal fenestra, mammalian affinities) and the Diapsida (two temporal fenestrae, avian affinities).

With

According to J. Piveteau (1955), subsequent studies by R. Owen, E.D. Cope, H.G. Seeley and T.H. Huxley led to establishment by H.F. Osborn* *(1903), on the basis of fossil reptiles*, of two major divisions according to the structure of the temporal region: the Synapsida (one single temporal fenestra, mammalian affinities) and the Diapsida (two temporal fenestrae, avian affinities).

NOTE 2.6

MORTILLET

Replace p.2.18, l. 29:

Mortillet, a fervent Darwinist keen to show the connection between material progress and the evolution of man, subdivided the Palaeolithic into 5 stages according to stone tool types. In 1883, he correlated these with glaciation events and put forward the concept of an Eolithic (Dawn Stone Age), predating the Palaeolithic and characterised by the very crude implements produced by the Tertiary ancestor of humans.

With:

Gabriel de Mortillet, *a French anthropologist and fervent Darwinist,* keen to show the connection between material progress and the evolution of man, subdivided the Palaeolithic into 5 stages according to stone tool types *(Chellean, Mousterian, Aurignacian, Solutrean, Magdalenian).* In 1883, he correlated these with glaciation events and put forward the concept of an Eolithic (Dawn Stone Age), predating the Palaeolithic and characterised by very crude implements produced by the Tertiary ancestor of humans (Mortillet*, 1883).

NYSTROEM & TEGENGREN: SWEDISH GEOLOGISTS IN CHINA

Andersson* (1929) relates how, since his appointment as the Director of the Geological Survey of Sweden in 1906, he had been involved, with Felix Tegengren, in an inquiry into the iron ore resources of Sweden. When the 11th International Geological Congress met in Stockholm in 1910, he was instrumental in the decision to invite all participating countries to cooperate in "an international inquiry into the iron-ore resources of the world" (Andersson, *ibid.*, p. 11). Another result of this involvement was the invitation of Andersson and Tegengren, by the Chinese Government, to cooperate with the Geological Survey of China in its investigation of the mineral resources of China (especially iron and coal resources). Andersson and Tegengren were not the first Swedish geologists to work in China: Erik Nystroem had been in China since 1902 where he was associated with the establishment of University of Taiyuanfu (in Shanxi Province) and had established "The Nystroem Institute for Scientific Research in Shansi". Nystroem is credited with establishing the initial cooperation between Chinese and Swedish geologists (Regnell*, 1991).

Leroy* (1971, p. 14), in his introduction to the published correspondence between Johan Gunnar Andersson and Pierre Teilhard de Chardin highlights the important cultural role played by Sweden in Republican China through its missionaries and scientists.

LICENT

See Note 3.1.

NOTE 2.7

Insert p. 2.20 after l. 19:

Sinanthropus will be examined in more details in Chap. 3, Para. 3.5 and 3.6.

NOTE 2.8

Replace p. 2.22, l. 8:

a new species of early man named *Eoanthropus dawsoni*.

With:

a new species of early man named *Eoanthropus dawsoni by A. S. Woodward (Reader, 1981, p. 61).*

NOTE 2.9

Spencer's work was not the last shot in a war of words that saw most of the participants in the Piltdown affair (and others) accused at one time or another. As Stephen Jay Gould put it, in his own argument for Teilhard de Chardin's guilt, "the solution to 'whodunit' becomes 'everybodydunit'" (Gould*, 1983, p. 201). Turritin* (1997), in his annotated bibliography of the Piltdown forgery, has listed 30 different interpretations of the case, published between 1955 and 1996.

NOTE 2.10

Replace p. 2.23, l. 19:

When Dart finally came to London with his original material, interest had shifted from the Taung specimen.

With:

When Dart finally came to London, *in 1931 (Reader, 1981, p. 92)*, with his original material, interest had shifted from the Taung specimen.

NOTE 2.11

Replace p. 2.29, l. 1:

According to LeGrand, the grounds for rejection of the continental drift model included the non-scientific methodology of Wegener, the distortion needed to make the modern continents fit into a past supercontinent, the connection between drift and geological catastrophism and the nature of Wegener's palaeoclimatological, biogeographical and geodetic evidence.

With:

According to LeGrand, the grounds for rejection of the continental drift model included the *allegedly* non-scientific methodology of Wegener, the distortion needed to make the modern continents fit into a past supercontinent, the connection between drift and geological catastrophism and the nature of Wegener's palaeoclimatological, biogeographical and geodetic evidence.

NOTE 2.12

Replace p. 2.31, l. 3 (below table):

(from Romer *et.al*, 1962; United States* under-represented in this survey because of inclusion criteria in Romer *et al.*, *ibid.*)

with:

(*bibliographic data obtained in* Romer *et.al*, 1962; United States* under-represented in this survey because of inclusion criteria in Romer *et al.*, *ibid.*)

Grafton Elliot Smith and Charles W. De Vis were the two Australians listed in Table 2.1. A re-examination of the data has shown that Heber A. Longman was initially listed among those whose country of origin could not be ascertained. Longman narrowly fits the criteria, with 5 pre-1920 papers listed; this omission is unforgivable, considering his career at the Queensland Museum. It is explained by the writer's decision to concentrate on the top 10% contributors and the availability of biographical information to the writer at the time of the study. A detailed analysis of the complete set of data is planned for publication in the future; this forthcoming study will also include those American contributors working on American material who have been under-represented in this study.

See also Note 2.2

NOTE 3.1

Further information about Père Emile Licent (p. 3.1):

Père Emile Licent (1876 – 1952) was a Jesuit from the Province of Lille (France) who, in his formative years, had undergone a religious and scientific training (specialising in entomology). He arrived in China in 1914 with a dream of setting up a "centre of Christian and scientific influence" (Cuénot[CH.3], 1958, p. 63, trans. by the author). This was the genesis of the Hoangho-Paiho Museum in Tianjin of which he was the curator and founder. After his arrival in China in 1914, Licent went on many field trips, mostly along the Huang He (Yellow River) valley to collect geological, zoological and botanical specimens for his museum.

In 1922, Licent travelled to Sjara-osso-gol in the southeastern corner of the Ordos Plateau in Inner Mongolia. In a bend of the Yellow River, he found a great variety of vertebrate fossils. Licent requested the expertise of a vertebrate palaeontologist, and Professor Marcellin Boule from the Museum of Natural History in Paris sent him Teilhard de Chardin, who arrived in China in 1923.

The collecting expeditions of Licent (1914 - 1924), and of Licent and Teilhard de Chardin as a team (1924 - 1935) are described in a series of memoirs subsequently published by Licent* (1924, 1935). These memoirs consist of a travel diary, including very detailed field trip notes illustrated by an atlas and photographs. The accuracy and exhaustive character of Licent's field notes are remarkable. They are still useful to modern palaeomammalian research as they are sometimes the only record left of sites now inaccessible (Tedford, 1993, pers. comm.). As well as detailed notes on the palaeontology and palaeoanthropology of the regions they visited, these diaries provide a very complete picture of natural history and contain some interesting observations on the local mores and politics, as well as the meteorology of the region.

Licent returned to France in 1938; he was succeeded, at the Hoangho Paiho Museum, by Père Pierre Leroy who became a collaborator of Teilhard de Chardin and established with him, in 1940, the Institute of Geobiology which became the repository for all the Hoangho Paiho collections. According to Leroy[CH.3] (1971, p. 94), Licent spent the rest of his life in Paris where he became the President of the French Entomological Society and worked on the Assidae. He died in Paris in 1952.

The life and career of Licent would indeed provide material for a very interesting study of the life and times of a Jesuit scientist in China in the first half of the twentieth century.

NOTE 3.2

Further information about Maurice Trassaert (p. 3.13):

According to Cuénot[CH.3] (1958), Maurice Trassaert was based at the Hoangho Paiho Museum, originally a physicist who was 'converted' by Teilhard de Chardin to palaeontology. Trassaert collaborated with Teilhard de Chardin on the Yushe fauna of south-eastern Shansi (Teilhard de Chardin & Trassaert, 1937a&b, 1938). Trassaert also co-authored a paper with Licent (Licent & Trassaert*, 1935) on the Pliocene stratigraphy of the same area.

NOTE 3.3

Correlation and differences between the Late Cenozoic formations of southern and northern China.

According to Teilhard de Chardin, Young, Pei & Chang* (1935), a tentative generalised correlation between the Late Cenozoic formations of South and North China can be established as follows:

	SOUTH CHINA	NORTH CHINA
Late Pleistocene	Dissection	Loess
Early Pleistocene	Laterites	Red Loams
	'South Asian' fauna with *Stegodon*	'Northern' fauna with *Euryceros* and *Dicerorhinus*
Late Pliocene	Boulder clays	Sanmenian lakes
	Erosion	Fenho erosional stage
Early Pliocene	Lakes	Lakes

This is corroborated by recent observations on the zoogeographical differences between Pleistocene faunas (especially mammals) of northern and southern China (Lucas[CH.3], 2001, p. 265): Pleistocene northern faunas have Palaearctic affinities while southern faunas have Oriental affinities.

NOTE 3.4

Replace p. 3.15, l. 5:

In a review paper published in 1933 (Black, Teilhard de Chardin, Young & Pei, 1933), *he* described the Zhoukoudian deposit. Teilhard de Chardin felt that it represented a distinct stage in the Late Cainozoic of China, intermediate between the Late Pliocene (Sanmenian) and the Early Pleistocene (Loess).

With:

In a review paper published in 1933 (Black, Teilhard de Chardin, Young & Pei, 1933), *the authors* described the Zhoukoudian deposit. Teilhard de Chardin felt that it represented a distinct stage in the Late Cainozoic of China, intermediate between the Late Pliocene (Sanmenian) and the Early Pleistocene (Loess).

NOTE 3.5

The Hoangho-Paiho Museum (Section 3.1) was named after the Pai Ho River (see Fig. 3.2) and Huang Ho River in northern China.

NOTE 3.6

Replace p. 3.18 l. 22:

Taklamakan Desert *(twice!)*,

With

Taklamakan Desert *(twice, as the expedition camels perished during the first attempt)*,

NOTE 3.7

Replace p. 3.26, l. 29:

Vincent Bendix, a rich Swedish-American from Chicago, was approached by Sven Hedin, *who wanted* to put together an ethnographic collection documenting the practice of Tibetan Buddhism (lamaism) in central Asia; accordingly, a contract was drawn up between Sven Hedin and Vincent Bendix:

With:

Vincent Bendix, a rich Swedish-American from Chicago, was approached by Sven Hedin. *Hedin wanted* to put together an ethnographic collection documenting the practice of Tibetan Buddhism (lamaism) in central Asia; accordingly, a contract was drawn up between Sven Hedin and Vincent Bendix:

Source:

According to Hedin & Bergman [CH.3](1943b, p. 61):

> From the very outset of the expedition I had cherished the hope that in the course of our journeys we might also be able to get together a really representative ethnographic collection from the interior of Asia and make a scientific investigation of the daily life of at least some of the many peoples in these parts of the world. Especially did I plan to gather all available material connected with Lamaism, of whose religious rites I had seen so many colourful examples in the course of my Tibetan travels.

NOTE 3.8

Replace p. 3.30, l. 23:

Total: 42 scientific reports (these 42 added to the 4 reports devoted to the history of the expedition add up to a total of 46 reports. These (out of a general total of 54 published) were all sighted by the author; the remainder were not available).

With:

Total: 42 scientific reports (these 42 added to the 4 reports devoted to the history of the expedition add up to a total of 46 reports. These (out of a general total of 51 published according to Gillispie, 1970, p. 217) were all sighted by the author; the remainder (Publications No: 41, 47, 48, 49, 50) were not available to the author.

NOTE 3.9

Lake Lop-Nor

The location of Lake Lop-Nor, known as the 'wandering lake' had been the subject of controversy as it had been observed and plotted in different places over time by the ancient Chinese cartographers and the Russian explorer Przhevalsky among others. Sven Hedin was able to demonstrate that the location of Lop-Nor had indeed shifted over time, as the result of the changing hydrodynamics of the Tarim Basin whose drainage waters empty into the lake.

NOTE 3.10

The statement about duplicates (p. 3.34) is based on Mateer & Lucas[CH.3] (1985)'s account of the Lagrelius Collection; the word 'duplicate' is used throughout and I suggest, from the context, that duplicates were made, in which case the word 'duplicate' would mean cast. This matter does require further clarification for publication.

NOTE 3.11

Replace p. 3.40 l. 26:
The Yen-ching-kou locality turned out to be of importance for its Pleistocene fauna.

With:

The Yen-ching-kou locality, *375 km East of Chengdu (see Fig. 3.10),* turned out to be of importance for its Pleistocene fauna. *This fauna included 25 genera of mammals including Stegodon and Rhinoceros (Granger in Andrews[CH.3], 1932, p. 516).*

NOTE 3.12

See Fig. A.1 for a summary of the stratigraphy of the Mongolian sediments and Fig. A.2 for a summary of the fossil discoveries.

Replace p. 3.41, l. 30:

A Palaeozoic invertebrate fauna recognised in the Jisu Honguer limestone beds of southern Mongolia indicated that the region was invaded by the sea during the Permian.

With:

A Palaeozoic invertebrate fauna recognised in the Jisu Honguer limestone beds of southern Mongolia indicated that the region was invaded by the sea during the Permian. *The Permian Jisu Honguer invertebrate fauna has been described extensively by Grabau[CH.3] (1931): it includes brachiopods, corals, bryozoans, pelecypods and gastropods.*

NOTE 3.13

Mongolia and China as the cradle of reptile and mammalian evolution.

Insert p. 3.43, l. 7 (after quote):

Evidence for the enduring legacy of the exploration of the fossil record of China and Mongolia was evaluated at a recent symposium (Beard & Dawson*, 1998) and forms an integral part of Lucas (2001)'s review of the fossil record of vertebrates in China.

[The developing understanding, during the 20th century, that Asia was indeed a centre of mammalian evolution from which taxa subsequently migrated to other regions of the globe, was evaluated at a symposium recently (Beard & Dawson*, 1998). According to Beard* (*in* Beard & Dawson, *ibid.*, p. 5):

> Asia is identified as the most likely ancestral area for a large number of placental mammal clades, including Perissodactyla, Artiodactyla, Cetacea, Dinocerata,

Tillodontia, Arctostylopidae, Pantodonta, Coryphodontidae, Rodentia, Alagomyidae, Lagomorpha, Primates and Hyaenodontidae.

Among these taxa, the Perissodactyla, the Alagomyidae and the Hyaenodontidae are understood to have originated in Mongolia (Beard, *ibid.*). Others such as Artiodactyla, Pantodonta, Rodentia and the Lagomorpha are thought to have originated in China. Lucas (2001)'s study of the Chinese vertebrate record corroborates the importance of the region for the development of reptiles and mammals.]

<u>NOTE 3.14</u>

Black applied for funds for both projects; the Turkestan expedition never took place because of Sven Hedin's successful bid.

<u>NOTE 3.15</u>

Insert p. 3.50, l. 14:

Franz Weidenreich (1873 – 1948) was a German anatomist and Professor of Anthropology at the University of Frankfurt who had specialised in the study of human skulls, tissues and the problem of human races. While he was a Visiting Professor at the University of Chicago in 1935, he was appointed by the Rockefeller Foundation a Visiting Professor at the Peking Union Medical College and the Honorary Director of the Cenozoic Research Laboratory (Shapiro[CH.3], 1974; Gregory*, 1949).

<u>NOTE 3.16</u>

Replace p. 3.53, l. 14

His main scientific work in the region was a collaboration with Bian Meinian on the Triassic reptiles of the Lufeng Basin (Yunnan Province), from which more than 20 scientific papers resulted, some of which appeared in international journals (*e.g.* Young, 1947).

With:

His main scientific work in the region was a collaboration with Bian Meinian *(who, like Jia Lanpo, had been associated with the Zhoukoudian excavations since the 1931)* on the Triassic reptiles of the Lufeng Basin (Yunnan Province), from which more than 20 scientific papers resulted, some of which appeared in international journals (*e.g.* Young, 1947).

<u>NOTE 3.17</u>

Minchen Chow (Zhou Mingzhen) is not to be confused with Chow (first name unknown), the Geological Survey geologist who was seconded to assist T.G. Halle, the Swedish palaeobotanist while he was doing field work in China.

<u>NOTE 3.18</u>

Comments on the Sino-Swedish Expeditions publications on Vertebrate Palaeontology
5 publications listed in Table 3.1

1. Bohlin* (1937a). Eine Tertiäre Säugetier-Fauna aus Tsaidam (Tertiary Mammal Fauna from Tsaidam.

This Tertiary fauna from Tsaidam (Qaidam, western Gansu) is the oldest *Hipparion*-bearing fauna in China and also comprises some Carnivora, Proboscidea, Cervidae (including a new species *Lagomeryx tsaidamensis*), Bovidae (including the new genera and species *Olonbulukia tsaidamensis*, *Qurliqnoria cheni* and *Tossunoria pseudibex* as well as the newly described *Tsaidomotherium hedini* Bohlin 1935), Giraffidae, Rhinocerotidae (including the new species *Dicerotherium tsaidamense*).

According to Lucas[CH.3] (2001, p. 242), the Tsaidam fauna is thus the oldest of the Bahean Land Mammal Age (Late Miocene) which begins with the appearance of *Hipparion* in China and shows a mixture of survivors of the preceding Tungurian Land Mammal Age, mammals characteristic of the Bahean Land Mammal Age and some unique taxa (the Bovidae).

2. Bohlin* (1937b). Oberoligozäne Saugetiere aus dem Shargeiltein-Tal (western Kansu)
3. Bohlin* (1942). The fossil mammals from the Tertiary deposit of Taben-buluk, Western Kansu - Insectivora and Lagomorpha
4. Bohlin* (1946). The fossil mammals from the Tertiary deposit of Taben-buluk, western Kansu – Simplicidentata, Carnivora, Artiodactyla, Perissodactyla and Primates

These three publications have been grouped together as they all deal with Late Oligocene localities from western Gansu: Shargaltein Gol and Taben Buluk. The Shargaltein Gol fauna comprises mostly Rodentia (Duplicidentata such as *Desmatolagus* and the new genus *Sinolagomys*, and Simplicidentata).
The Taben-buluk fauna content is listed in the titles: the most noteworthy, according to Bohlin* (1942), is the new genus *Sinolagomys* and the presence of a primate jaw fragment and possible tooth. Bohlin (*ibid.*) notes the similarity between the Taben-buluk fauna, the Hsanda-gol fauna from Mongolia collected and described by the Central Asiatic Expedition (Matthew & Granger*, 1924), and the Saint Jacques fauna (Ordos Basin) described by Teilhard de Chardin[CH.3] (1926a).
According to Lucas (2001, p. 222), the Taben-buluk fauna, however, is slightly younger (Late Oligocene) than either the Hsanda-gol or the Saint-Jacques fauna which are Early Oligocene in age. The Taben-buluk fauna first described by Bohlin (1942, 1946) is the basis for the establishment of the Taben-bulukian Land Mammal Age (Lucas, *ibid.*).

5. Bohlin* (1951). Some mammalian remains from Shih-her-ma-ch'eng, Hui-hui-p'u area, Western Kansu.

The highlight of the mammalian assemblage in this locality is a new genus and species, *Mimolagus rodens*, which was attributed to the Duplicidentata (lagomorphs). This assemblage was estimated to be from the earlier part of the Tertiary but could not be dated more precisely.

According to Lucas (2001), the relationship of lagomorphs to rodents has long been a disputed question and it is only recently that the Glires (including rodents and lagomorphs) have been divided into Simplicidentata (rodents and mixodonts) and Duplicidentata (lagomorphs).

The importance of *Mimolagus* is highlighted by Carroll* (1988) who describes it as one of the most primitive of the lagomorphs and may indeed belong to the group which is ancestral to both rodents and lagomorphs, the order Anagalida which originated in Asia.

6. Bohlin* (1953). Fossil Reptiles from Mongolia and Kansu.

This paper describes a variety of Archosauria (mostly Dinosauria) and Chelonia collected by the Sino-Swedish Expedition in several Mesozoic localities of Mongolia and Gansu. The Archosauria assemblage is similar to that collected by the Central Asiatic Expedition (with *Protoceratops*, *Velociraptor* and possible *Psittacosaurus* species) but much poorer in quality. The Chelonia assemblage contains several new genera: *Peishanemys*, *Tsaotanemys* and *Yumenemys*. *Peishanemys* is of particular importance as it is one of the key taxa for the Khukhtekian (Early Cretaceous) land-vertebrate age, along with *Psittacosaurus* and the mammal *Gobiconodon* (Lucas, 2001, p. 170).

NOTE 4.1

Many other elements also played a part in the introduction of western technology to China at the beginning of the twentieth century. In the geological field, in particular, it was a time when western institutions and mining companies were sending geologists to China in order to assess the resources of China (as in the case of Johan Gunnar Andersson). Another example of this trend is

Robert Logan Jack, an Australian geologist who, along with his son, Robert Lockhart, and his friend J. Fossbrook Morris (both engineers), examined the metalliferous deposits of Sichuan Province for the English Pioneer Company (Branagan*, 1997).

NOTE 4.2

Replace p. 4.1, l.4

The first flourishing of vertebrate palaeontology...

With:

A major flourishing of vertebrate palaeontology...

Table A.1 – Summary Table of palaeontological discoveries in China and Central Asia during the 1920's and the 1930's

DATE	LICENT & TEILHARD DE CHARDIN (See Section 3.1)	SINO – SWEDISH EXPEDITIONS (See Section 3.2)	CENTRAL ASIATIC EXPEDITIONS (C.A.E.) (See Section 3.4)	J.G. ANDERSSON, D. BLACK & ZHOUKOUDIAN (See Sections 3.3, 3.5 & 3.6)
1930 - 1936				Excavations at Zhoukoudian bring up remains of more than 40 individuals, stone artifacts and burnt bones and abundant vertebrate fauna. Extension of the site to include 20 localities (including Upper Cave and *Homo sapiens sapiens*.
1932 - 1935	T. de C. collaborates with C.C. Young on correlation of Cenozoic deposits in China			
1933	Discovery of Yushe Basin Fauna (T. de C & L.) Review paper on Zhoukoudian (T.de C. *et al.*, 1933)			
1934	Summary of new discoveries at Zhoukoudian (T. de C. & Pei, 1934)	THIRD PERIOD		
1936				
1940	Foundation of the Peking Institute of Geobiology			
1941				Disappearance of Zhoukoudian human fossils

Summary Table of palaeontological discoveries in China and Central Asia during the 1920's and the 1930's (Continued)

Table A.2 – Late Cainozoic stratigraphy of North China

	LATE CAINOZOIC STRATIGRAPHY OF NORTH CHINA (Teilhard de Chardin & Licent [CH.3], 1924; Licent & Teilhard de Chardin[CH.3], 1925; Teilhard de Chardin & Young[CH.3], 1933; Teilhard de Chardin*, 1937	LATE CAINOZOIC STRATIGRAPHY OF NORTH CHINA (Meyerhoff *et al.**,1991)	LAND MAMMAL AGES OF CHINA (Lucas[CH.3], 2001)	EUROPEAN STAGES (Meyerhoff *et al.**,1991)
HOLOCENE		Brown-Yellow & Black soils		
UPPER/LATE PLEISTOCENE	Neolithic Black	- Glacial deposits and soils - Loess & soil deposits - Glacial deposits & yellow-brown soils	SALAWUSUAN	Wurmian Riss-Wurmian
MIDDLE PLEISTOCENE	Paleolithic Yellow Earths	-Reddish clays -Glacial deposits with brown clays	ZHOUKOUDIANAN	Rissian Mindel-Rissian Mindelian
LOWER/EARLY PLEISTOCENE	Sanmenian Reddish clays	-Lacustrine clays -Glacial deposits -Lacustrine/fluvial clays/sands	NIHEWANIAN	Gunz-Mindelian Gunzian **Villafranchian**
UPPER/LATE PLIOCENE			YOUHEAN	Astian Plaisancian Pontian
LOWER/EARLY PLIOCENE	Pontian Red Earths With *Hipparion richthofeni*		JINGLEAN	
UPPER/LATE MIOCENE		Yellow/gray mudstones/sandstones	BAODEAN BAHEAN	Sarmatian Vindobonian

Late Cainozoic stratigraphy of North China

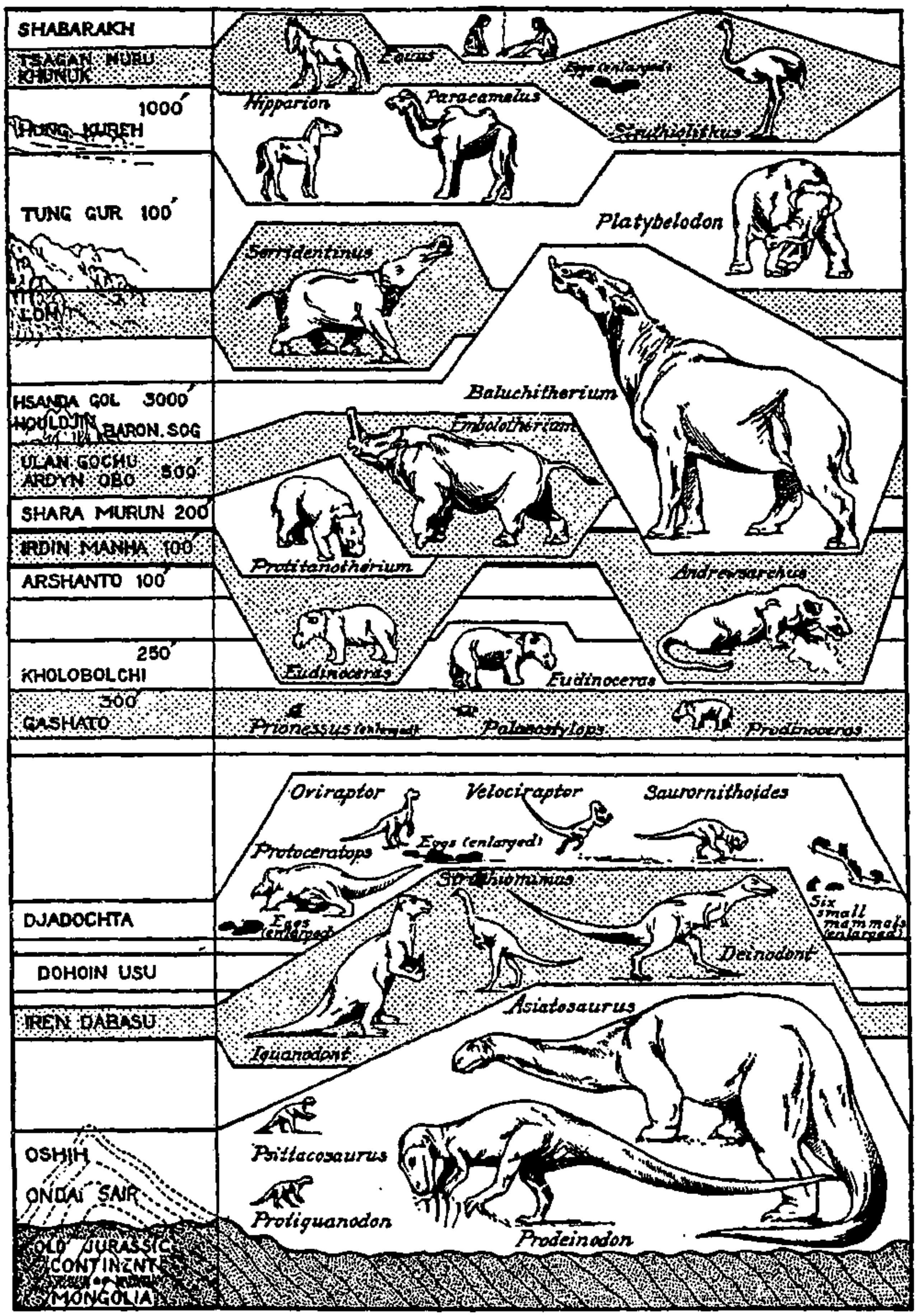
Fig. A.1 – Mongolian Formations from the Lower Cretaceous to the Recent.

SUMMARY OF MONGOLIAN FORMATIONS, FAUNAS AND GEOLOGIC HISTORY FROM JURASSIC UP

Era	Period	Epoch	Formation	Thickness	Types of sediment	Chief fossils	Igneous activity	Diastrophism
CENOZOIC	QUATERNARY	Recent	Shabarakh	50'	Upper part, dune sands	Upper culture: Pottery, arrow-points, grinders, hearths	None	None
					Lower part, shallow lake deposits, clays, sands and minor gravels	Mesolithic culture: hammer-stones, flakes, scrapers, egg-shell beads. Horse, Antelope	None	None
		Pleistocene	Orok Nor	5±	Washed gravels of Gobi upland and higher river benches	Primitive stone artifacts	None	None
			Tsagan Nuru	50±	Sands and fine gravels	Struthiolithus, ? mastodont, Rhinocerid, large Cervid	None	None
			Joselungi	12'	Gobi upland gravels	No fossils	None	None
			Uljitundur	300±	High alluvial fans of the Altai front	No fossils found	None	Slight warping
			Bilik Gol	20±	Sands with interbedded soil	Fragments of artiodactyls	None	None
			Gachu	1000±	Coarse rubbles (on ridges along the Altai front)	Fragment of unidentified bone	None	Faulting and tilting
			Khunuk	130'	Buff sands and clays	Equus, Rhinoceros, Gazelle, ? [illegible]	None	Slight warping
	TERTIARY	Pliocene	Tung Gur	500±	Variegated clays, sandstones, coarse sands	Amebelodon, Rhinocerid, Canid, etc.	None	None
			Pang Kiang	300±	Chiefly red clayey sands and light gray gravels	Rodent	None	None
			Hung Kureh	2000±	Yellow and white sands, gray clays	Hipparion, Gazella, etc.	None	Faulting, tilting and minor folding
			Loh	100±	Olive green and brown clays and gravels and possibly white sandy beds	[illegible] and Baluchitherium	None	Faulting and warping
		Oligocene	Hsanda Gol	300±	Red clays and sands, light yellow sands, with gravels, rubbles and tuffs below	Baluchitherium; large microfauna.	Basalt flows	Faulting and warping
			[illegible]; Hsanda Gol Extension in Khunuk Valley	200±	Red sands and clays, gray sands	Baluchitherium fauna	Basalt flows	Warping
			Houldjin	40'	Yellow gravels and sands	Baluchitherium and Entelodon	None	None
			Baron Sog	30'	White and drab sands and clays	Largest Titanotheres and Baluchitherium	None	None
			Elegen	160±	White arkoses and brown clays	Titanothere	None	Warping
			Ardyn Obo	500'	Yellow sands and gravels above; gray and red clays below.	Cadurcotherium fauna	None	None
			Ulan Gochu	200±	Red clays and white sandstones	Titanotheres with elongate, clubbed nasals (Embolotherium)	None	None
		Eocene	Shara Murun	200±	White gravels and sands above; Brown, red and greenish clays below.	Protitanotherium mongoliense fauna	None	None
			Tukhum	150±	Hard red clay under Shara Murun	Teilhardia	None	None
			Ulan Shireh	150±	Red clays with minor gray and yellow beds	Chalicotheres and Titanotheres	None	None
			Irdin Manha	100±	Gray to white gravels, sands and clays	Protitanotherium (Manteoceras) fauna; Andrewsarchus	None	None
			Kholobolchi	250±	White to rusty and drab gravels, sands and clays	Amblypod skulls	None	Warping and faulting
			Arshanto	100±	Hard red clay and lenses of gray sandstone	Schlosseria	None	None
			Gashato	300'	Red and brown clays and gray gravels and sands	Palaeostylops fauna	Basalt flows	Slight warping
UNCONFORMITY: SLIGHT DISTURBANCE WHICH IS MOST MARKED NEAR THE ALTAI RANGES								
MESOZOIC			Djadochta	500'	Fine red sand and red clay	Protoceratops fauna	None	Slight warping
		Lower Cretaceous	Iren Dabasu	80'	Gray clays, gray sandstones and red clays	Iguanodonts and Struthiomimids	None	Slight warping
			Doholn Usu	300±	Red clays and sands; grey sandy clays	Iguanodonts, Crocodiles, Turtles, Gastropods		
			Dubshih	1000±	Conglomerates, sandstone, thin limestone; rhyolite tuff and ash	Pelecypods and Gastropods		Faulting and tilting
			Ochungchelo	2000±	Basal conglomerate; gray and red clay and sand	Sauropod fragment	None	Faulting and tilting
			Tairum Nor	100'	Red and white clays, ferruginous sandstone and limestone	Small dinosaur and wood		Faulting and tilting
			Baiying Bologai	150'	Red gravels, sands and clays	Large dinosaurs, indet.	None	Slight warping
			Jasu Jergulung	100±	Paper shales	Estheria	None	None
			Go Yoto	250±	Silts and fine sands (probably aeolian)	None found	None	None
			Shirigu	?	Sands and clays	Fragments of dinosaurs	Basalt flows	Faulting and tilting
			Oshih	2000±	Conglomerates, sands, clays, paper shales and thin limestones	Psittacosaurus, Prodeinodon, Asiatosaurus	Basalt flows; extinct hot springs	Faulting and warping
			On Gong	500±	Sands and clays	Diplodocus-like Sauropod	None	Warping and folding
			Ondai Sair	500±	Sands and paper shales	Protiguanodon, Sauropod and Lycoptera fauna	None	Faulting and tilting
GREAT UNCONFORMITY: ALL FORMATIONS BELOW THIS ARE AT LEAST PARTLY FOLDED AND FORM THE OLD ROCK FLOOR OF THE GOBI REGION								

Mongolian Formations from the Lower Cretaceous to the Recent.
(from Andrews[CH.3], 1932, p. 566).

Fig. A.2 – **Fossil Fauna of Mongolia from the Lower Cretaceous to the Recent**



Fossil Fauna of Mongolia from the Lower Cretaceous to the Recent (see Fig. C.1 for corresponding ages of the Mongolian formations).
(from Andrews[CH.3], 1932, p. 567).

REFERENCES

ANDERSSON, J.G., 1929. The origin and aims of the Museum of Far Eastern Antiquities. *Bulletin of the Museum of Far Eastern Antiquities (Stockholm)* 1, pp. 11 – 27.

ANDREWS, S.M., 1985. Rhizodont crossopterygian fish from the Dinantian of Foulden, Berwickshire, Scotland, with a re-evaluation of this group. *Transactions of the Royal Society of Edinburgh: Earth Sciences* 76, pp. 67 – 95.

BEARD, K.C. & DAWSON, M.R., 1998. The dawn of the age of mammals in Asia. *Bulletin of Carnegie Museum of Natural History* 34.

BENNETT, A. A., 1967. *John Fryer: The introduction of Eastern Science and Technology into Nineteenth-Century China.* Harvard East Asian Monographs No 24, Harvard University Press, Cambridge, Mass.

BLACK, D. 1927. On a lower molar hominid tooth from the Chou Kou Tien deposit. *Paleontologia Sinica*, Series D, 7(1).

BOHLIN, B., 1937a. Eine Tertiäre Säugetier-Fauna aus Tsaidam. *Reports from the Scientific Expedition to the north-western Provinces of China under the leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 1.

BOHLIN, B.,1937b. Oberoligozäne Saugetiere aus dem Shargeiltein-Tal (western Kansu). *Reports from the Scientific Expedition to the north-western Provinces of China under the leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 5.

BOHLIN, B., 1942. The fossil mammals from the Tertiary deposit of Taben-buluk, Western Kansu - Insectivora and Lagomorpha. *Reports from the Scientific Expedition to the north-western Provinces of China under the leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 20.

BOHLIN, B., 1946. The fossil mammals from the Tertiary deposit of Taben-buluk, western Kansu – Simplicidentata, Carnivora, Artiodactyla, Perissodactyla and Primates. *Reports from the Scientific Expedition to the north-western Provinces of China under the leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 28.

BOHLIN, B., 1951. Some mammalian remains from Shih-her-ma-ch'eng, Hui-hui-p'u area, Western Kansu. *Reports from the Scientific Expedition to the north-western Provinces of China under the leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 35.

BOHLIN, B., 1953. Fossil Reptiles from Mongolia and Kansu. *Reports from the Scientific Expedition to the north-western Provinces of China under the leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 37.

BONE, E.L., 1999. Teilhard de Chardin, Pierre. *In* SINGER, R. (Ed.). *Encyclopedia of Paleontology.* Fitzroy Dearborn Publishers, Chicago, pp. 1225 – 1226.

BRANAGAN, D.F., 1997. Robert Logan Jack, Geologist in China. *Proceedings of the 30th International Geological Congress* 26, pp. 177 – 186.

CARROLL, R.L., 1988. *Vertebrate Paleontology and Evolution.* Freeman and Co, New York.

COLBERT, E.H., 1992. *William Diller Matthew Paleontologist – The Splendid Drama Observed.* Columbia University Press.

DEBAINE-FRANCFORT, C., 1999. *The Search for Ancient China.* Thames & Hudson.

FAIRBANK, J.K., Ed., 1983. *The Cambridge History of China, Vol. 12, Republican China 1912 – 1949, Part 1.* Cambridge University Press.

FAIRBANK, J.K. & FEUERWERKER, A., Eds, 1986. *The Cambridge History of China, Vol. 13, Republican China 1912 –1949, Part 2*. Cambridge University Press.

FORBES, E., 1846. On the connexion between the distribution of the existing fauna and flora of the British Isles, and the geological changes which have affected their area, especially during the epoch of the northern drift. *Memoirs of the Geological Survey of Great Britain* 1, pp. 336 – 432.

GAUDRY, A., 1872. Sur des ossements d'animaux quaternaires que M. l'abbé David a recueillis en Chine. *Bulletin de la Société Géologique de France* XXIX (2), pp. 177-179.

GOLDBERG, P., WEINER, S. *et al.*, 2001. Site formation processes at Zhoukoudian, China. *Journal of Human Evolution* 41, pp. 483 – 530.

GOULD, S.J., 1983. *Hen's Teeth and Horse's Toes*. W.W. Norton, New York. Pp. 201 – 226.

GREGORY, W.K., 1949. Franz Weidenreich, 1873 – 1948. *American Anthropologist* 51, pp. 85 –90.

HEDIN, S., 1931. *Across the Gobi Desert*. Routledge & Sons, 1931.

HEDIN, S., 1991. *My Life as an explorer*. Oxford University Press.

HOWELLS, W.W., 1966. *Homo erectus. Scientific American* 215(5), pp. 46 – 53.

KLEIN, R.G., 1989. *The Human Career – Human Biological and Cultural Origins*. University of Chicago Press.

LAURENT, G., 1995. Paléontologie et évolution chez Teilhard de Chardin. *Mémoires de la Société géologique de France* 168, pp. 97 – 100.

LAVAS, J.R., 1993. *Dragons from the Dunes – The Search for Dinosaurs in the Gobi Desert.* Published by the author, P.O. Box 14-421, Panmure, Auckland.

LE GROS CLARK, W.E., 1955. *The fossil evidence for human evolution.* 1st ed., University of Chicago Press.

LE GROS CLARK, W.E., 1964. *The fossil evidence for human evolution.* 2nd ed., University of Chicago Press.

LEROY, P., 1971. *Dans le Sillage des Sinanthropes – Lettres Inédites de Pierre Teilhard de Chardin et Johan Gunnar Andersson 1926 – 1934.* Fayard.

LICENT, E., 1924. *Compte-Rendus de Dix Années de Séjour et d'Exploration dans le Bassin du Fleuve Jaune, du Pai Ho et des autres Tributaires du Golfe de Pei Tcheu Ly.* Librairie Française, Tientsin.

LICENT, E., 1935. *Compte-Rendus de 11 Années (1923-1933) de Séjour et d'Exploration dans le Bassin du Fleuve Jaune, du Pai Ho et des autres Tributaires du Golfe de Pei Tcheu Ly.* Mission de Sienhsien, Race Course Rd, Tientsin.

LICENT, E. & TRASSAERT, M. 1935. The Pliocene lacustrine series in central Shansi. Bulletin of the Geological of China 14, pp. 211-219.

LIU, D.S. & LU, Y.C., 1991. P. Teilhard de Chardin's contributions to the scientific exchanges between China and the West. *In* WANG, H.Z., YANG, G.R. & YANG, J.Y. (Eds). *Interchange of Geoscience Ideas between the East ad the West.* Proceedings of the XVth International Symposium of INHIGEO, October 25 – 31, 1990, Beijing. China University of Geosciences Press.

LUCAS, S., 2002. Walter Granger, 1872 – 1941, Paleontologist. *New Mexico Museum of Natural History and Science Bulletin* 19, 58 pp.

MATTHEW, W.D & GRANGER, 1924. New Carnivora from he Tertiary of Mongolia. *American Museum Novitates* 97.

MAYR, E., 1950. Taxonomic categories in fossil hominids. *Cold Spring Harbor Symposia on Quantitative Biology* 15, pp. 109 – 118.

MEYERHOFF, A.A., KAMEN-KAYE, M., CHEN, C. & TANER, I., 1991. *China – Stratigraphy, Paleogeography and Tectonics.* Kluwer Academic Publishers, Dordrecht.

MORTILLET, G. de, 1883. *Le Préhistorique*. Paris.

OSBORN, H.F., 1903. The reptilian subclasses Diapsida and Synapsida and the early history of the Diaptosauria. *Memoirs of the American Museum of Natural History* 1.

PERKINS, J., 1981. *To the ends of the Earth – Four Expeditions to the Arctic, the Congo, the Gobi, and Siberia.* Pantheon Books, New York.

PRESTON, D.J., 1988. *Dinosaurs in the Attic – An Excursion into the American Museum of Natural History.* Ballantine Books, New York.

REGAL, B., 2002. *Henry Fairfield Osbom - Race and the Search for the Origins of Man.* Ashgate Publishing Co.

REGNELL, G., 1991. Swedish Geologists in China. In WANG, H.Z., YANG., G.R. & YANG, J.Y. (Eds). *Interchange of Geoscience Ideas between the East and the West.* Proceedings of the XVth International Symposium of INHIGEO October 25 – 31, 1990, Beijing.

RICH, P.V., ZHANG, Y.P., CHOW, M.C., WANG, B.Y., KOMAROWER, P., FAN, J.H., SLOSS, R., MOODY, J.K.M. & DAWSON, J., 1994. *A Chinese –*

English and English – Chinese Dictionary of Vertebrate Paleontology Terms. Monash University, Melbourne.

SHAPIRO, H.L., 1981. Davidson Black: An appreciation. *In* SIGMOND, B.A. & CYBULSKI, J.S., Eds. *Homo erectus – Papers in Honor of Davidson Black.* University of Toronto Press, pp. 21 - 26.

SHU, D., LUO, H., CONWAY MORRIS, S., HANG, X., HU, S., CHEN, L., HAN, J., HU, M., LI, Y. & CHEN, L., 1999. Lower Cambrian vertebrates from south China. *Nature* 402, pp. 42 - 46.

SINGER, R. (Ed.). *Encyclopedia of Paleontology.* Fitzroy Dearborn Publishers, Chicago.

SUN, A., 1973. A new Species of *Dicynodon* from Sinkiang. *Vertebrata PalAsiatica* 11, pp. 52 – 58.

TEILHARD DE CHARDIN, P., 1934. Nécrologie – Davidson Black. *L'Anthropologie* XLIV, pp. 424 – 426.

TEILHARD DE CHARDIN, P., 1937. The Pleistocene of China – Stratigraphy and correlations. *L'Anthropologie* 47, pp. 211 – 220.

TEILHARD DE CHARDIN, P., 1967. *Letters from a Traveller.* Fontana Books.

TEILHARD DE CHARDIN, P., BREUIL, H. & WERNERT, P., 1939 – 1940. Les industries lithiques de Somalie Française. *L'Anthropologie* XLIX(1939-1940), pp. 497 – 522.

TEILHARD DE CHARDIN, P., BREUIL, H. & WERNERT, P., 1951. Le Paléolithique du Harrar. *L'Anthropologie* XLIX(1951), pp. 219 – 230.

TEILHARD DE CHARDIN, P. & PIVETEAU, J., 1930. Les mammifères fossiles de Nihowan (Chine). *Annales de Paléontologie* XIX, pp. 1 – 134.

TEILHARD DE CHARDIN, P., YOUNG, C.C., PEI, W.C. & CHANG, H.C. (1935): On the Cenozoic formations of Kwangsi and Kwangtung. Bulletin of the Geological Society of China XIV, pp. 179 – 210.

THULBORN, R.A & WADE, M., 1979. Dinosaur stampede in the Cretaceous of Queensland. *Lethaia* 12, pp. 275 – 279.

TOBIAS, P.V., 1985. The former Taung Cave system in light of contemporary report and its bearing on the skull's provenance: early deterrents to the acceptance of *Australopithecus*. *In* Tobias, P.V., Ed. *Hominid Evolution: Past, Present and Future*, Alan R. Liss, New York, pp. 25 –40.

TURRITIN, T., 1997. *A Mostly Complete Piltdown Man Bibliography.*
Available:
http://www.talkorigins.org/faqs/piltdown/piltref.html
Accessed: 5 February 2003.

WALLACE, J., 1994. *The American Museum of Natural History's Book of Dinosaurs and Other Ancient Creatures*. Simon & Schuster, Australia.

WILSON, E.O., 1975. *Sociobiology: The New Synthesis.* Harvard University Press, Cambridge, Mass..

YOUNG, C.C., 1935. On two skeletons of Dicynodontia. *Bulletin of the Geological Society of China* 14, pp. 483 – 517.

YOUNG, C.C., 1939. Additional Dicynodontia remains from Sinkiang. *Bulletin of the Geological Society of China* 19, pp. 111 – 136.

YUAN, P.L. & YOUNG, C.C., 1934. On the discovery of a new dicynodon in Sinkiang: *Bulletin of the Geological Society of China* 13, pp. 563 – 574.

INTRODUCTION

The aim of this thesis is two-fold:

1. To try and reconstruct a major episode in the history of vertebrate palaeontology: the multinational exploration of the fossil vertebrate of China and Central Asia during the 1920's and 1930's, and its implications for vertebrate palaeontology as a whole and for the development of a Chinese palaeontological community . During the second decade of the twentieth century, the fossil vertebrate record of Central Asia became a focus of interest to the international palaeontological community. The hypothesis that Central Asia was the cradle of mammalian evolution was proposed by Osborn (1910) and Matthew (1915). A multinational effort set out to confirm or refute this hypothesis and, in the process, achieved much more:
   - It considerably expanded current knowledge of the central Asiatic fossil vertebrate record
   - Osborn's and Matthew's hypothesis was confirmed
   - The Peking Man site in Zhoukoudian was discovered
   - As result of these new discoveries, and particularly in response to the need for the systematic study of the Zhoukoudian site, funds and personnel were poured into the region and cooperative ventures set up with the Geological Survey of China, leading to the foundation of the Cenozoic Research Laboratory and the development of a Chinese palaeontological community.
   - The palaeontological discoveries made during the 1920's and 1930's form the basis of current palaeontological thinking about the region and about the evolution of vertebrates, in particular reptiles and mammals (Lucas, 2001).

2. To analyse this episode in the development of a scientific community in a non-western setting, and show the importance of cognitive (internal) and socio-cultural (external) factors in this process. The episode under study is a

perfect example of the close connection between the two kinds of factors, which can be integrated into a model

This thesis will look at different aspects of this question in each chapter:

Chapter 1 considers the historical background which has had such a dramatic impact on paleontological research during the period, framing it between the troubled end of the long, stable and inward-looking dynastic age and the search for a new political regime which culminated in the founding of the People's Republic of China in 1949. In its agony, the dynastic regime looked for ways of dealing with increasing threats from foreign powers and, out of the perceived need to acquire Western technology, a scientific community started to develop, in China, at the turn of the twentieth century. Geological sciences were among the first to grow and provided the institutional environment within which the growing interest in the fossil record could be accommodated.

Chapter 2 examines the state of vertebrate palaeontology at the turn of the twentieth century, from a double perspective, conceptual and bibliographical. After a survey of the development of palaeontological science with special emphasis on the fossil record of the major vertebrate groups, this chapter carries out a bio-bibliographic analysis of the main contributors to palaeontology between 1880 and 1920. As a result, the importance of the fossil record of China and Central Asia for the evolution, origin and dispersal of vertebrates (especially reptiles and mammals) is highlighted.

Chapter 3 describes the multinational exploration of the fossil record of China and Central Asia, and the interaction between the main groups and the Geological Survey of China. As a result of this interaction, knowledge of the fossil record of the region was substantially increased, Peking Man was discovered in Zhoukoudian and a cooperative venture set up between the Rockefeller Foundation and the Geological Survey of China, leading to the foundation of the Cenozoic Research Laboratory in Peking.

Chapter 4 addresses the nature of the factors that have controlled the dynamics of the development of vertebrate palaeontology in China. This analysis is carried out from a History of Science perspective as this case study lends itself to a multidimensional account of scientific activity and of the epistemological and socio-cultural spaces in which it is situated. A review of models for the transfer of scientific disciplines across cultures is presented and a model for the present case is suggested.

Preliminary versions of this work have been presented to the 19th International INHIGEO Symposium (Komarower, 1994) and the 30th International Geological Congress (Komarower, 1997).

REFERENCES

KOMAROWER, P., 1994. The fossil vertebrate record of Central Asia and China: discovery and exploration in the 1920's. *In* BRANAGAN, D.F. & MCNALLY, G.H. (Eds). *Useful and Curious Geological Enquiries Beyond the World – Pacific – Asia Historical Themes.* The 19th International INHIGEO Symposium, Sydney, Australia, 4 – 8July 1994, pp. 89 – 102.

KOMAROWER, P., 1997. Science across cultures: The case of vertebrate palaeontology in China. *In* WANG, H., BRANAGAN, D.F. et al. (Eds). *Comparative Planetology, Geological Education, History of Geology.* Proceedings of the 30th International Geological Congress, Beijing, China, 4 – 14 August 1996, pp. 251 – 260.

MATTHEW, W.D., 1915. Climate and Evolution. *Annals of the New York Academy of Sciences XXIV*, 171-318.

OSBORN, H.F.,1910. *The Age of Mammals in Europe, Asia and North America*. The Macmillan Company, New York.

CHAPTER 1

SCIENCE, SOCIETY AND POLITICS IN CHINA AT THE BEGINNING OF THE 20TH CENTURY

1.1- CHINA IN THE LATE 1800'S AND THE EARLY 1900'S: A SNAPSHOT VIEW

1.1.1 – The decline of the dynastic age

At the turn of the nineteenth century, the Qing Dynasty had reached its peak: under the reign of Emperor Qianlong (1736 – 1796), China had become a prominent power in Asia, and managed to protect its own territory from the expansionist tendencies of other powers, Western and Asian. The Manchu decline that followed this 'golden age' was the result of external pressures involving trade and politics, and internal tensions arising from official corruption, disenchantment with Manchu rule, and nationalism.

During the nineteenth century, the contacts between China and the West were primarily commercial and missionary in nature. Indeed, it was as a sideline to the missionaries' primary enterprise that most of the knowledge about Western science and technology was initially introduced into China. Missionaries had started arriving in China at the end of the sixteenth century and, along with Christianity, brought with them Western scientific concepts about mathematics, astronomy, geography, hydraulics, the calendar and the manufacture of cannon (Teng and Fairbank, 1979).

During the following two centuries, the Jesuits were joined by a host of other missionaries, coming from a variety of national backgrounds and representing several streams in the Christian tradition, both Roman Catholic and Protestant. By 1865, there were over thirty Christian denominations present, originating in England, the United States, Sweden, France, the German states, Switzerland and Holland (Spence, 1990). The presence of the missionaries had generated some negative reactions among the Chinese throughout the nineteenth century, culminating in the Tianjin massacre of 1870 during which sixteen French nationals (including ten nuns) were killed. According to Spence (1990), throughout the period, the missionaries had a profound impact on Chinese education, mainly through the development of mission schools and the translation of historical and scientific as well as religious texts.

Commercial contacts between China and the West took place through the offices of chartered merchants in Hong Kong and were virtually monopolised by the British. Until 1842, there was no treaty regulating the commercial relations of China with the outside world. Military defeat at the end of the two "Opium Wars" with England (1839 – 1842; 1856 – 1860) brought about a series of treaties (with England, France and the United States) in which China lost some of her sovereign rights. According to Ch'en (1979, p.31):

> In more concrete terms, the new treaty system, which in part preserved and in part broke down traditional Chinese diplomatic practice, consisted of the stationing of resident envoys at Peking and of consuls at the treaty ports, the establishment of foreign settlements, the organization of a modern maritime customs service under joint control, and the creation of mixed courts presided over by Chinese and foreign officers. In addition, as France was interested in protecting and furthering the efforts of missionaries, China was forced to open her doors to the Gospel, Western missionaries, like Western traders, coming in under the protection of extraterritoriality.

At the same time, during the second half of the nineteenth century, China was facing a series of internal rebellions: these were ethnic and religious in nature and included the Christian-Confucian Taiping rebellion (1850 – 1864), the Miao and Hakka rebellions (1855 – 1857) and the Muslim rebellion in western China (1863 – 1873).

These external and internal events ultimately contributed to the fall of the Qing dynasty in 1912. The Emperor Xianfeng, who had reigned over the period of the treaties, died in 1861 and was succeeded by his consort, Cixi, who acted as a regent for her son, Tongzhi, and, eventually, named two successors to the imperial throne after Tongzhi died in 1875, shortly after his accession to the throne. Guangxu, the ninth Emperor of the Qing dynasty, was only four when he was named Emperor, thus allowing Cixi to hold on to power as a regent until 1889. Guangxu died in 1908, one day before the Empress Dowager Cixi and was succeeded by Puyi, the tenth and last Emperor of the Qing dynasty.

1.1.2 – The search for 'self-strengthening'

The response to the growing perception of China's weakness in front of Western technology is charted in Teng and Fairbank's survey (1979): after the defeat of the Opium Wars, it became quite clear that, in order to build its own defences against foreign incursions, China had to "strengthen itself" and acquire knowledge of and means to acquire Western technology. In a memoir presented to Zeng Guofan in 1861, the general who put an end to the Taiping Rebellion, the scholar Feng Guifen argued that Chinese students should study foreign languages, mathematics and science in addition to classical Chinese texts.

> Western books on mathematics, mechanics, optics, light, chemistry, and other subjects contain the best principles of the natural sciences. In the books on geography, the mountains, rivers, strategic points, customs, and native products of the hundred countries are fully listed. Most of this information is beyond the reach of our people.
>
> ......
>
> If today we wish to select and use western knowledge, we should establish official translation offices at Canton and Shanghai. Brilliant students up to fifteen years of age should be selected from these areas to live and study in these schools on double rations. Westerners should be invited to teach them the spoken and written languages of the various nations, and famous Chinese teachers should also be engaged to teach them classics, history and other subjects. At the same time, they should learn mathematics.
>
> (Quoted in Teng & Fairbank, 1979, p. 51)

In the following years, the self-strengthening movement resulted in the development of "new structures to handle foreign relations and collect customs dues, to build modern ships and weapons, and to start teaching international law and the rudiments of modern science" (Spence, 1990, p. 216). However, in spite of these successes, there was, widespread among the Chinese intelligentsia, a feeling that science in general, and Western science and technology in particular, was outside their Confucian brief as men of knowledge and part of the foreign aggression they were being subjected to (Buck, 1974).

In 1895, at the end of the Sino-Japanese War which saw more territorial losses for China (Taiwan and the Pescadores), the Confucian scholar Kang

Youwei, widely read in western literature as well as the Chinese classics, gathered together a petition signed by 1300 candidates at the metropolitan examinations in Peking. This "Memorial presented by the examination candidates" urged the Emperor Guangxu to carry out a large number of reforms, some of which aimed at the "relaxation of the strict traditional qualifications in favour of men of ability" and "reform of the civil service examinations, promotion of more schools and more translation of western books for the training of men of ability, bestowal of rewards or medals to encourage new inventions" (Teng & Fairbank, 1979, p. 148). Even though this memorial failed to have any immediate effect, it paved the way for a later effort. In 1898, following a series of further territorial concessions to foreign powers (Germany, Britain, Russia, France and Japan), Kang Youwei obtained an audience with the Emperor Guangxu and managed to persuade the Emperor to engage on a path of reforms.

> Our late teacher again presented his views in detail on the translation of books, the sending of students to study abroad, the dispatching of high officials to travel abroad, and such matters. After he had finished one topic, he would pause for a time to await the command of the Emperor. When the Emperor still did not order him to arise, he again discussed the employment of the right persons and the execution of administrative affairs. Finally he spoke about promoting ideas of reform in society in order to inspire the wisdom of the people and to encourage their spirit. He also talked about inviting surrender from and pacifying the rebels in the secret societies.
> (Quoted in Teng & Fairbank, 1979, p. 179)

There followed an extraordinary period of three months, the Hundred Days' Reforms (June – September, 1898), during which a series of edicts was issued, aimed at four main areas: reform of the examination system, education, economic development and the armed forces (Spence, 1990). However the conservative reaction was swift and, on 21 September 1898, the Emperor was imprisoned following the order of the Empress Cixi who resumed the regency.

It was not until the Boxer Uprising of 1900 and its aftermath, that the examination system was finally abolished in 1905. This measure had far-reaching implications as it created a new class of intellectuals who were no longer committed to the government establishment. The Boxer Protocol, signed in 1901 after the suppression of the Boxer Uprising, exacted the payment by China of a huge indemnity, part of which was used by the United States to fund travelling scholarships for Chinese students.

1.1.3 – Reform and revolution: The rise of the Republican age

Meanwhile, Sun Yat Sen was gathering support in Southern China and the Chinese community in Japan for his Tongmenhui (Great League Party): their aim was to unite nationalistic forces and overthrow the Qing (Manchu) dynasty. Antimanchuism was the glue holding these forces together and only did so until the fall of the Qing. The first rebellion broke out in Wuchang (Hubei Province) on October 10th, 1911 and spread northward with most provinces, one after the other, repudiating Peking's authority.

In February 1912, the Emperor Puyi, who had been put on the throne (aged three) in 1908, just before Cixi died, abdicated, and the Republic of China was declared, with Sun Yat Sen as temporary president. The presidency was later surrendered to Yuan Shikai, whose death in 1916 opened up an era of confusion and violence. China split up into a number of independent provinces governed by despotic military leaders during a period which became known as the Warlord Era.

In 1919, a student movement, the May Fourth Movement, originated as a result of student demonstrations against the Japanese take-over of German concessions in Shandong Province. At the same time, a new culture and way of thinking were starting to develop. The slogan ' Worship Darwin instead of Confucius' illustrates this new thinking, which created a fertile ground for seeding Western science, even though there was a strong nationalistic feeling. These two contrasting threads, interest in Western science and technology on one hand, and fervent nationalism on the other, have remained entwined until the present time.

In 1921, the Communist Party was founded. It subsequently formed an uneasy coalition with Sun Yat Sen and the Guomingdang. In 1925, Sun Yat Sen died and, during the following year, Chiang Kai-Shek led the Northern Expedition of his Nationalist army: this resulted in the reunification of China under his Nanjing-based government. However, this did not bring peace and stability, as two new factors emerged: the Communists split away from the coalition and began to establish bases in Southern China; the Japanese invaded Manchuria in 1931 and the rest of China in 1937. In 1938, Chongqing, in the southwestern province of Sichuan, became the capital of China.

This very schematic outline of Chinese history during the second half of the nineteenth century and the first forty years of the twentieth century has highlighted the troubled relation of China with foreign powers, which framed the emerging Chinese interest in modern science and technology. This troubled relation was one of the multitude of elements that has made life so challenging during this period, for the Chinese people themselves and for visitors to China, whether or not engaged in the exploration of its fossil vertebrate record.

1.2 - SCIENCE, TRADITION AND INSTITUTIONS IN REPUBLICAN CHINA

In this attempt to sketch the state of science in Republican China, it is worth bearing in mind N. Sivin's warning. In his introduction to the collection of papers presented to a conference on science and medicine in twentieth-century China (Bowers, Hess & Sivin, 1988), Nathan Sivin warns the reader against two kinds of accounts of Chinese science in this period: one kind, based on an internalist (cognitive) view of the history of science, tends to see "the science of the prewar Republic as a march of progress" (Sivin, *ibid.*, p. xv); the other kind of account, inspired by the externalist (sociological) view, sees "Republican science as a failure" (*ibid.*), in comparison with other, wealthier countries. An example of the later view is found in Buck (1980). Sivin (*ibid.*) recommends a middle ground and lists a number of questions that need to be answered: what prompted the Chinese government to support science? How well was the governmental science policy carried out? What did motivate the vocation of Chinese scientists?

No attempt will be made here to answer the first two questions, which are beyond the ambit of this section. But the careers of a number of intellectual figures will be sketched in order to provide some elements of an answer to Sivin's third question, and set the scene for the study of the development of vertebrate palaeontology, which is the subject of this thesis. These men also represent the tension between classical education and scientific learning, between the need for China to reform and the attachment to traditional Chinese values, especially in reaction to the horror of the First World War.

1.2.1 - Yen Fu and the introduction of Darwinism to China

Yen Fu (1854 – 1921) is often described as the scholar-translator who introduced Darwin to China. In fact, he does not appear to have translated any of Darwin's texts; he was, though, the translator and commentator of Huxley 's Evolution and Ethics and Other Essays, in which he introduces Herbert Spencer's views on the application of Darwinism to human societies and discusses how to adapt those Social Darwinist ideas to Chinese needs (Pusey, 1983).

According to Boorman & Howard (1970), Yen Fu's career took a turn when, for financial reasons, he was forced to discontinue his classical education at his father's death. Yen Fu obtained a scholarship at the Naval Academy attached to the Foochow (Fuzhou) shipyard and was one of the first Chinese students sent to study in Europe. He arrived in England in 1877 where he spent two years at the Greenwich Naval College and became interested in politics and Social Darwinism. Upon his return to China in 1879, he taught for a year at the Foochow Naval Academy and was soon appointed Dean of the new Peiyang Naval Academy in Tientsin (Tianjin). However, he decided to improve his career prospects, and he sat and repeatedly failed the traditional civil service examination. At this point, in 1895 he turned to writing and journalism. Along with others, he founded a periodical National News, devoted to the publication of material translated from western and Japanese sources (Teng & Fairbank, 1979). In 1897, he published in National News, his translation of the first two chapters of Huxley's Evolution and Ethics (which had been published in English in 1893): this was the beginning of his career as a translator – commentator, in which he sought to improve the content of the Chinese education he thought was necessary as a "first step on China's way to strength". The full translation of Huxley's Evolution and Ethics appeared in 1898 with the extensive footnotes and commentaries that became Yen Fu's trademark as a translator. It was followed by the translation of several seminal texts such as Adam Smith's

Inquiry into the Nature and Causes of the Wealth of Nations, J.S. Mill's On Liberty, H. Spencer's Study of Sociology and many more.

In this, Yen Fu was joining the translation effort that was started, as part of the "self-strengthening" movement in the 1860's and was flourishing in many centres. One such centre was the Kiangnan arsenal in Shanghai where two translators, Hsü Shou (a failed candidate at the civil service examination with an interest in western scientific literature) and John Fryer (a British missionary and translator of technical manuals into Chinese), were laying the foundations for the development of chemical science and technology in China during the 1860's and 1880's (Reardon-Anderson, 1991).

At the turn of the twentieth century, Yen Fu gradually became disenchanted with the revolutionary turn taken by the reform movement and saw in the turmoil that followed the establishment of the Chinese Republic in 1912 a proof that the Chinese people was not yet ready for western-style government and, after the First World War, his own admiration for the West was shattered by the casualties of the war: "I feel that the three centuries of progress of their races have only accomplished four things, that is, to be selfish, to kill others, to have no integrity, and to lose the sense of shame" (quoted in Teng and Fairbank, 1979, p.151).

It is not surprising, then, that Yen Fu associated his fortunes with Yuan Shikai in his attempt to transform the presidency of the new republic into an imperial position. Yen Fu became the first chancellor of Peking University in 1912, when it was modernised; he helped nurture it as a centre of learning, research and teaching, and saw the development of a new generation of intellectuals who were to be prominent members of the May Fourth Movement in 1919, a result he probably would not have approved of.

1.2.2 – Hu Shi, the May Fourth Movement and the Science Society

Hu Shi (1891 – 1962) was born and educated in Shanghai where he received a 'modern' education including English, mathematics and science at the China National Institute, an institution established in 1905 by a group of Japan – educated Chinese intellectuals. In 1910, he passed the Boxer Indemnity Scholarship examination and departed for the United States where he spent the next five years at Cornell University and Columbia University, studying philosophy after a frustrated attempt at agricultural science. At Cornell, he discovered the writings of John Dewey and went on to do a Ph.D. under Dewey, on "The Logical Method n Ancient China", a study of pragmatism in early Chinese philosophy (Boorman & Howard, 1970). The philosophical and educational ideas of John Dewey, centred on a pragmatic view of knowledge, were to have a life-long influence on Hu Shi and lead him to develop the experimentalist methodology, which he applied to the reevaluation of Chinese traditional culture and recommended for the solution of political and social problems that were occupying the minds of the Chinese intellectuals, who were the inspiration of the Peking University-based May Fourth movement.

Hu Shi came to represent one of the two currents of scientism described by Kwok (1965). Scientism, which advocates the use of the induction-based scientific method to all aspects of knowledge, was used in China as a weapon against classical Chinese values. Kwok (*ibid.*) describes two streams of scientism: materialistic scientism, which emphasises the ultimate material nature of the universe, and empirical scientism, which stresses the experience-based nature of knowledge and the use of induction. Hu Shi was a proponent of the empirical scientistic view as a result of the importance of Dewey's thought on his intellectual development.

While at Cornell, Hu Shi was involved in the formation of the Science Society by a group of Chinese Cornell students who had come to understand that one of the reasons that China had been so slow to acquire Western science and technology was the absence of a scientific organisation designed for the interaction between scientists, students and, through the promotion of science, the general public. According to Buck (1974, p. 161): " The Society was one of the first privately created and completely Chinese scientific organizations to be brought into being and, at least until the creation of the Academia Sinica in 1928, probably the most important association of scientists in China". The initial aim of the Science Society was the publication of the journal <u>Science</u>, but gradually it expanded its activities and engaged in a variety of projects such as sections devoted to specific branches of science, translations, the development of standards for Chinese scientific terminology and, upon its return and implantation in China, the development of a scientific library. At the same time, it evolved from a forum where ideas about science were discussed, to an institution where science was done by what was becoming a "thoroughly professional community". Among the early members of the Society, were V.K. Ting (Ting Wenchiang) and Wong Wenhao, who were so important in the development of geology in China (see Para. 1.3).

Soon after his return to China in 1917, Hu Shi was appointed Professor of Philosophy at Peking University, with which he was to be associated for most of the following thirty years, including a two-and-a-half year spell as its Chancellor in 1946. His leading role in the promotion of the vernacular as a literary language in replacement of the classical written form, his association with the review New Youth (the organ of the intellectual avant-garde and their campaign against traditional values) and John Dewey's lecture tour in 1919, made Hu Shi one of the figureheads of the May Fourth movement. This movement had started as a student demonstration in Tiananmen Square on 4 May 1919 against the unfair terms of the Treaty of Versailles and had soon expanded into a broad movement, cultural and political, aimed at finding a way to cope with the three main problems faced by China at the time: warlordism, an exploitative landlord system and foreign imperialism (Spence, 1990).

These years represent the intellectual peak of Hu Shi's influence and are sometimes called his 'Chinese years'. He left China again in 1937 and spent the major part of the remaining 25 years of his life in the United States, where he was named Chinese ambassador in 1938. He came back to China briefly when he was appointed chancellor of Peking University and left again in 1948, fleeing the Communist forces approaching Peking. In 1958, he went to Taiwan where he had been made President of Academia Sinica and died there, in 1962.

1.2.3 – Research and higher education: A survey of the new institutions

According to Sun (1986), the development of research institutions was made possible by a class of intellectuals, mostly foreign-educated and keen to reconcile the Chinese and Western cultural traditions. The early phase of this development (between 1898 and 1928) was characterised by an important foreign component, both in the training of the scholars and the funding of institutions. The preferred study destination was Japan, until rising Japanese imperialism and Chinese nationalism made it a less popular destination, and it was replaced by Western Europe and the United States. Soon after the new Republic of China came into being in 1912, a conference was convened by the Education Minister, Tsai Yuanpei, to examine the needs of an integrated national system. By 1922, there were 37 higher education institutions located in various parts of the country: 5 national universities, 2 provincial universities, 13 private universities and 17 Christian universities (Sun, *ibid.*, p. 378).

External funding for education came primarily from the United States, out of the returned Boxer Indemnity funds, and was, at first, used to fund the education of Chinese students in the United States (from 1908), and later to set up a preparatory school in China for prospective Boxer scholars; this school later became Tsinghua College (1926) and Tsinghua University (1928). The remainder of the Boxer Indemnity Fund was used to set up the China Foundation for the Promotion of Education and Culture in 1925; the governing board of the China Foundation included ten Chinese members (diplomats, scientists such as Ting Wenchiang, from the Geological Survey, and education leaders), and five American members such as John Dewey (from Columbia University) and Roger Greene, the director of the Peking Union Medical College (itself funded by the Rockefeller Foundation). Boxer indemnities returned by other countries such as France, Britain and Italy were also used in part to finance education (Sun, *ibid.*).

During this early period, several scientific organisations came into being besides the Science Society, which had begun in 1914 at Cornell University and was successfully transplanted in China in 1918 upon the return of its founding members (see Para 1.2.2). The earliest of these new organisations were the Geological Survey of China (founded in 1916) and the Geological Society (founded in 1922), and these will be examined in more detail in Para 1.3. They were joined in 1926 by the Chinese Meteorological Society and, in 1927, by the Fan Memorial Biological Institute, established under the auspices of the China Foundation.

The central research academy, Academia Sinica, was established in 1928 under the Nanking-based Guomingdang government of Chiang Kaishek; the first president of Academia Sinica was Tsai Yuanpei, a scholar with a traditional Chinese and a European education, who had served as the first minister of education of the Republic (1912 – 1913) and chancellor of National Peking University (1917 – 1927). Academia Sinica was administered by a secretary-general (Ting Wenchiang served as the second secretary, between 1934 and 1936) and received advice from the National Science Council. The research institutes, though, were the raison d'être of Academia Sinica; there were ten: Physics, Chemistry, Engineering, Geology, Astronomy, Meteorology, History & Philology, Psychology, Social Sciences, and Zoology & Botany. The director of the Institute of Geology, between 1928 and 1949, was Li Ssu-kuang (J.S. Lee), a British-educated geologist with an interest in fusulinids, stratigraphy and geomechanics, and a professor at Peking University (Sun, *ibid.*; Chen, Sun & Cui, 1991). The distribution of research institutes across disciplines reflects the strong interest in natural sciences and the emerging importance of fieldwork (in contrast to the classical tradition of literary research). The early successes of this new approach, including the discovery of Peking Man and the growing understanding of the Chinese fossil vertebrate record which are the subject of this thesis, demonstrated its value.

In spite of the recurrent funding restrictions, there was much progress in research during the Nationalist 'Nanking Decade' (1927 – 1937), stimulated by the dual aim of placing "Chinese science on an equal footing with that of other modern countries" (Sun, *ibid.*, p. 403), and laying the foundations for industrial development. A large number of journals now existed for the publication of research results, including nine journals in geology and palaeontology. The role of the China Foundation, which controlled the deployment of the returned Boxer Indemnity Fund, became gradually integrated with that of Academia Sinica, as it financed science professorships, research fellowships and institutions, such as the Fan Memorial Institute of Biology.

1.3 - GEOLOGY AND PALAEONTOLOGY IN CHINA AT THE BEGINNING OF THE TWENTIETH CENTURY

1.3.1 – V.K. Ting, Wong Wenhao and the emergence of geology in China

The story of the development of geological sciences in Republican China is closely linked with that of V.K. Ting (Ting Wenchiang) and Wong Wenhao although, of course, there is more to those two men than their geological careers, and the development of geological research and institutions owes important contributions from other elements.

V.K. Ting and Wong Wenhao

V.K. Ting (1887 – 1936) has been described by his American biographer (Furth, 1970) as "a geologist by profession" but also "an official, journalist, businessman, polemicist and educator - a leader of the Peking academic establishment in the 1920's and the 1930's and one of the important personalities of China's 'new culture' movement" (Furth, *ibid.*, p. v). After a classical education in his native Jiangsu Province, Ting went to Japan (like many of his contemporaries) for further studies, at age 15, where he became involved with the political activism of the Chinese student community and did not complete any course of studies during his two years there. His scientific education was to take place in Great Britain (upon the recommendation of a friend who was studying in Scotland), where he graduated in geology at the University of Glasgow in 1911, seven years after his arrival. According to Furth (*ibid.*, p. 25):

> Ting reached England as a young adolescent, and he left as a grown man whose character had been deeply influenced during the intervening years. From a boy full of incoherent revolutionary sentiment and a commitment to 'save China with study', he had developed into a professionally minded adult with an ambition focused purposefully upon the scientific modernization of his country – both technical and intellectual.

In Britain, Ting found the passions that governed his whole life (besides politics) - science ("the intellectual mistress of his life" (Furth, 1970, p. 26)), philosophy (social Darwinism and scientific positivism) and travel. Upon his return to China in 1911, he found himself in the very exciting position of a geological scientist in a country virtually unmapped, thus recapturing the "catholicity of classical nineteenth-century naturalists" (Furth, *ibid.*, p. 32), such as Darwin and Huxley, who had influenced him so much.

Ting spent the following year (1912) in Shanghai where he taught science at the Nanyang Middle School while the Qing Dynasty was giving way to the Republic of China; in 1913, Ting went to serve as the head of the geology section in the Department of Mining Administration of the Ministry of Industry and Commerce, a dramatic turn for a fresh graduate, resulting from the decision of the new republic to support geological research as part of the scientific modernisation of China (Yang, 1988). In the same year, the Geological Institute, the first school of geology in China (apart from an unsuccessful attempt by the Imperial University of Peking in 1909), was established: Ting and Chang Hungchao, a graduate from the University of Tokyo were soon joined by Wong Wenhao. The Institute lasted three years and produced 18 graduates who were going to form the nucleus of the Geological Survey founded in 1916.

In 1912, Wong Wenhao (1889 – 1971) had become the head of the mining section of the Ministry of Industry and Commerce immediately upon his return from Belgium where he had obtained a doctorate in physics and geology at the University of Louvain (Boorman & Howard, 1970). The two men were to become life-long friends and colleagues and their careers were closely associated, although Ting's was cut short in 1936, when he died from asphyxiation while on a field trip, inspecting coal resources. Wong's career was much longer, serving in the various governments and surviving the tumultuous political changes in China during the greater part of the twentieth century.

Geology and geological education

In the early years, the dual task of training geologists and doing geological research was carried out by the Geological Institute. Ting went on extensive geological surveys of southwest China where, with the generalist mindset of a nineteenth century naturalist, he surveyed ore resources, fossil remains and the tribal customs of the non-Chinese peoples of the region (Boorman & Howard, 1970). The only extant guide to Chinese geology at the time was the work of Ferdinand von Richthofen, the German geographer, who, in the course of seven expeditions in China between 1868 and 1872, managed to construct an outline of the geological structure of China (Richthofen, 1877 – 1912).

Ting and his colleagues argued successfully that the government should concentrate on geological research, and the exploration and exploitation of resources, while the training of geologists should be entrusted to universities. Thus, the Geological Survey was founded in 1916, and the first Department of Geology was set up at Peking University in 1918. According to Lee (1985), the faculty of the new Department of Geology initially only included a mineralogist (Wang Lieh, who had studied at Freiberg, Germany) and an economic geologist (He Chieh, who was trained at Lehigh University, U.S.A.); by 1920, it had invited an eminent palaeontologist and stratigrapher, the American Amadeus Grabau (1870 –1946) from Columbia University, and a University of Birmingham-trained Chinese geologist, Li Ssu-Kuang (J.S. Lee, 1889 – 1971) who, along with Ting and Wong, were to shape the development of geology and palaeontology in China during the subsequent years. The success of this first department of geology spawned others and, by 1936, four other universities included departments of geology (Chungyang University in Nanking, Chungshan University in Canton, Tsinghua and Chungking University in Sichuan), and 264 geology graduates had been trained.

Geology and geological institutions

The Geological Survey of China was the first of three national institutions in charge of geological research; two others followed: the Nanking-based Institute of Geology of Academia Sinica founded in 1928, and the Geological Institute of the National Academy of Peiping (founded in 1929), which was, in fact, such a close affiliate of the Geological Survey (Yang, 1988) that it does not really gain mention as a separate organisation. The Geological Survey of China was founded in 1916 and its first Director was Ting Wenchiang (until 1921), followed by Wong Wenhao (1921 – 1935), and both men guided the young Survey from a poorly staffed, poorly resourced organisation to one of the best research institutions in China (Yang, 1988), one that had a "legitimate position in the international learned world: its scholars were known; its journals were read; its research made a genuine contribution to knowledge of the natural history of the earth" (Furth, 1970, p. 57). Because of the initial emphasis of the Survey on areas that served the mining industry, such as geological mapping, studies of mineral resources and exploration, they were able to attract funding from mining companies as well as the government. The association of foreign specialists with the Survey such as J.G. Andersson (the Swedish mining advisor: see Chap. 3) and A.W. Grabau was critical in securing joint projects and funding from overseas institutions. By 1931, the Geological Survey of China had acquired a Palaeontology Laboratory (invertebrate fossils), a Cenozoic Research Laboratory (vertebrate fossils and palaeoanthropology), a Soil Laboratory, a Seismological Laboratory, a Library and a Museum; it also published seven journals and one geological map series (1:1,000,000) (Lee, 1985, p. 69).

The work of the Geological Survey of China was facilitated by the existence of regional surveys, mostly in the southern part of China, reflecting the southern focus of the Nationalist government. By 1928, there were four: in Henan, founded in 1928, Hunan (1927), Guangdong (1927) and Jiangxi (1928). These regional surveys had a very practical orientation and were closely associated with local mining companies (Yang, 1988; Lee, 1985).

The Research Institute of Geology of Academia Sinica, one of its largest institutes, had a more theoretical orientation. Between 1928 and 1949, it was headed by Li Ssu Kuang, who was also Professor of Geology at the Department of Geology of Peking University and cooperated closely with the Geological Survey of China as a result of the presence of Ting Wenchiang and Wong Wenhao on the board of Academia Sinica. However, the Institute tended to concentrate on southern field areas (while the Survey concentrated on the North of China) and it had a special interest in glaciation and structural geology, reflecting the research focus of Li Ssu Kuang. The Institute published its own journals (Memoirs, Monographs and Contributions).

As a result of the emergence of the new geological institutions and the increasing number of professional geologists (both Chinese and foreign), working in China at the beginning of the 1920's, the need for an independent professional organisation led to the foundation, in 1922, under the guidance of Ting Wenchiang, of the Geological Society, whose aim was to: "afford an opportunity, for full and free discussion of the principles and problems of our science.... for intercourse with the scientific men in all parts of this country by bringing them together at intervals in our large meetings" (Ting Wenchiang, 1922, quoted in Lee, 1985, p. 128). According to Furth (1970, p. 52), it also afforded a unique forum for Sino-foreign contacts and cooperation in the geological field. Indeed, the membership comprised many foreign geologists and palaeontologists, including Teilhard de Chardin, A.W. Grabau, J.G. Andersson and others. The Geological Society also invited corresponding members, based overseas but with an interest in geological research in China and its main publication, Bulletin of the Geological Society of China, was published mainly in English (Lee, 1985).

1.3.2 – The state of vertebrate palaeontology in China around 1915

Classical and pre-scientific age of palaeontology in China

A survey of the beginnings of palaeontology in China would not be complete without a brief account of " classical " pre-scientific palaeozoological and palaeobotanical knowledge in China, which, according to Needham (1959), can be defined as pre-Linnaean in character (Linnaeus published his seminal work on taxonomy, Systema Naturae, in 1735.). This stage dates back to the third century A.D.: Chang Hua is often quoted in subsequent encyclopedias as having described the petrification of all pine trees after an interval of 3,000 years (Needham, *ibid.*, p. 612).

Fossil bamboo shoots were described during the Sung Dynasty period (960 – 1279 AD). A specific example can be found in Lu Yu's Lao Hsüeh An Pi Chi (Notes from the Hall of Old Learning): A landslide is described in the Yanzhou area (Shaanxi Province), uncovering a petrified bamboo forest at a depth of several dozens of feet, in an area where no bamboos were growing at the time.

According to Wang, Xiao & Tao (1989), the most interesting reference to invertebrates concerns brachiopods: they were called stone-swallows and incorporated into pharmaceutical compendia from 660 A.D. onwards (the stone-swallows were dissolved in acetic acid and used as a calcium substitute). Li Dayuan described their flying about during thunderstorms; this theory was later disproved by a Sung scholar Du Wan in his Cloud Forest Lapidary (1133).

> The stone swallows are produced at Lingling in Yongzhu (in Hunan Province). It was said in ancient times that they flew about while raining. In recent years, however, I have climbed to high cliffs, and found many of these stones with the form of swallows. Some of them I marked with my pen. As the rocks were exposed to the blazing sun they cracked and weathered. When thunder showers came, and the ones I had marked fell to the ground one after another. It was because of the expansion in the heat and contraction in the cold that they 'fly' through the air. They cannot really fly.
> (quoted in Wang, Xia & Tao, *ibid.*)

The first reference to fossil vertebrates concerns fishes and dates back to the sixth century A.D.: they were prized for aesthetic, not medical, reasons and used as charms. This led to the manufacture of reproductions. The bones and teeth of fossil reptiles, birds and mammals were known as 'dragon's bones'. They were first incorporated into the pharmacopoeia much earlier than the above-mentioned stone-swallows (around 133 B.C., during the Han dynasty).

According to Needham (1959, p. 622), much information about fossil remains has accumulated since the Han dynasty; when compared with Western pre-Renaissance writers, Chinese writers on fossil remains were more precise and showed a greater comprehension of the geological significance of fossils (this is evidenced in the stone-swallow example described above. Needham (1959, p. 623) writes:

> Brilliant insights or great achievements were attained by the Greeks, but from about the second to the fifteenth century A.D., China was more advanced than Europe, until modern science began to appear.

This corresponds to the period of the Western ' Great Interruption' which affected many disciplines during the medieval period.

Early vertebrate palaeontology in China

There is general agreement (Zhou, 1991; Lucas, 2001) that the beginnings of the scientific study of the Chinese vertebrate fossil record can be traced back to the description, in 1870, by Owen of fossil material that

was brought to him by Robert Swinhoe, who had served in Formosa (Taiwan) as a British Consul. This material, probably Pleistocene in age, had been collected "from a cave, many miles inland – he believed on the course of the Yang-tse-kiang" (Owen, 1870, p.434) and included mostly teeth from elephants, hyaenas, rhinoceros, a tapir and a clawed perissodactyl. Owen compared his material with the fossils collected by Falconer, an English botanist, who worked in India and collected much vertebrate fossil material from the Tertiary rocks of the Siwalik Hills, which are part of the sub-Himalayan Range. Falconer himself is credited with the first published description in 1846 of Chinese late Quaternary mammals from the Nixi Pass, on the northern slopes of the Himalayas in Southern Tibet.
Other early descriptions include those by Gaudry (1872) and Lydekker (1881, 1891, and 1901) and concern mainly fossil mammal material. The geographical and stratigraphical provenance of this material was often very difficult to ascertain as the following example shows:

> The specimen was obtained by Messrs. Webb & Trail from Tibetan traders, by whom it was brought from the Hundes plain, on the far side of the Niti Pass; and it was presented to the Society by Capt. Webb.
> (Lydekker, 1901, p. 289)

In the course of his expeditions in China between 1868 and 1872, Ferdinand von Richthofen collected vertebrate fossils that were subsequently described by E. Koken (1885). According to Zhou (*ibid.*), thirty-five mammalian species were described (including nine new ones), mostly from what became known as the Mio-Pliocene *Hipparion* fauna of North China. One of those species, *Hipparion richthofeni*, is of particular stratigraphic importance.

The single most important source of vertebrate fossil remains, though, was found in medicine shops, where they were sold as 'dragon bones', for their therapeutic properties, commensurate with the powerful characteristics of the dragon in Chinese mythology. Dragon bones were collected and sold by peasants, who thus became important sources of information, right down to the present day (Jia & Huang, 1990). At the turn of the century, K.A.

Haberer, a German physician working in Peking started collecting these 'dragon bones' from medicine shops. Upon his return to Germany in 1903, he donated his collection to the vertebrate palaeontologist Max Schlosser. This collection was the basis of Schlosser's seminal paper on Chinese mammals (1903), listing a total of ninety-two species which Schlosser attributed to the Neogene and Quaternary although, obviously, no stratigraphic information had been collected. Among these remains was one tooth, which was tentatively attributed to *Homo*. The presence of this tooth, as well as the then still recent discovery of Java Man (*Pithecanthropus erectus*) led Schlosser to propose that primates may well have originated in Asia, an idea that was developed a few years later by Henry Fairfield Osborn in his The Age of Mammals in Europe, Asia and North America (1910) and William Diller Matthew in his Climate and Evolution (1915).

These two books fuelled an increasing international interest in the fossil vertebrate record of China and Central Asia. As the products of their time, they represent the outcome of over a century of developments in vertebrate palaeontology: these form the subject of the following chapter.

REFERENCES

BOORMAN, H.L. & HOWARD, R.C., 1970. *Biographical Dictionary of Republican China.* Columbia University Press, New York.

BOWERS, J.Z., HESS, J.W. & SIVIN, N., 1988. *Science and Medicine in Twentieth-Century China: Research and Education.* Center for Chinese Studies, The University of Michigan.

BUCK, P., 1974. Western science in Republican China: Ideology and institution building. *In* Thackray, A. & Mendelsohn, M. (Eds): *Science and Values – Patterns of Tradition and Change.* Humanities Press, New York.

BUCK, P., 1980. *American Science and Modem China 1876 – 1936.* Cambridge University Press.

CH'EN, J., 1979. *China and the West - Society and Culture 1815 - 1937.* Hutchinson of London.

CHEN, Q., SUN, D. & CUI, S., 1991. Professor Li Siguang (J.S. Lee)'s contributions to the development of geological sciences in China. *In* Wang, H., Yang, G. & Yang, J. (Eds): *Interchange of Geoscience Ideas between the East and the West.* China University of Geosciences Press.

FURTH, C., 1970. *Ting Wen-chiang – Science and China's New Culture.* Harvard University Press.

GAUDRY, A., 1872: Sur les ossements d'animaux quaternaires que M. l'Abbé David a recueillis en Chine, *Bulletin de la Société Géologique Française* 2(29), pp. 177-179.

JIA, L. & HUANG, W., 1990. *The Story of Peking Man – From Archaeology to Mystery.* Foreign Languages Press, Beijing and Oxford University Press, Hong Kong.

KOKEN, E., 1885. Über fossile Säugethiere aus China, nach dem Sammlungen des Herrn Ferdinand Freihernnn von Richthofen bearbbeiter. *Geologisches Paläontologisches Abhandlungen* 3, pp. 31 – 113.

KWOK, 1965. *Scientism in Chinese Thought 1900 – 1950.* Yale University Press, New Haven and London.

LEE, T.Y., 1985. *Geological Sciences in Republican China, 1912 – 1937.* Unpublished Ph. D. thesis, State University of New York at Buffalo.

LUCAS, S.G., 2001. *Chinese Fossil Vertebrates.* Columbia University Press, New York.

LYDEKKER, R., 1881. Observations of ossiferous beds of Hundes in Tibet. *Records of the Geological Survey of India* 14, pp. 178-184.

LYDEKKER, R., 1891. On a collection of mammalian bones from Mongolia, *Records of the Geological Survey of India* 24, pp. 207-211.

LYDEKKER, R., 1901. On the skull of a chiru-like antelope from the ossiferous deposits of the Hundes (Tibet), *Quarterly Journal of the Geological Society of London* 57, pp. 289-292.

MATTHEW, W.D., 1915. Climate and Evolution. *Annals of the New York Academy of Sciences XXIV*, pp. 171-318.

NEEDHAM, J., 1959. *Science and Civilization in China.* Cambridge University Press, Cambridge, Vol. 3 (Mathematics and the Sciences of the Heavens and the Earth), pp. 611 – 623.

OSBORN, H.F.,1910. *The Age of Mammals in Europe, Asia and North America*. The Macmillan Company, New York.

OWEN, R., 1870. On fossil remains of mammals found in China. *Quarterly Journal of the Geological Society of London* 26, pp. 417 – 434.

PUSEY, J.R., 1983. *China and Charles Darwin.* Harvard University Press

REARDON-ANDERSON, J. 1991. *The Study of Change – Chemistry in China, 1840 – 1949.* Cambridge University Press.

RICHTHOFEN, F. von, 1877 – 1912. *China: Ergebnisse einer Reisen und darauf gregündeter Studien.* 5 vols; D. Reimer, Berlin.

SCHLOSSER, M., 1903. Die fossilen Saugethiere Chinas nebst einer Odontographie der recenten Antilopen. *Abhandlungen bayer Akademie der Wissenschaften 22*, pp. 1 - 221.

SPENCE, J., 1990. *The Search for Modern China*. W.W. Norton & Co, New York.

SUN, E-tu Zen, 1986. The growth of the academic community 1912 – 1949. *In* Fairbank, J.K. & Feuerwerker, A. (Eds). *The Cambridge History of China*. Vol. 13: Republican China 1912 – 1949, Part 2. Cambridge University Press, Cambridge.

TENG, S. & FAIRBANK, J.K., 1979. *China's Response to the West – A Documentary Survey, 1839 – 1923.* Harvard University Press.

WANG, H., XIA, X. & TAO, S., 1989. *A Brief History of Geology in China*. The Geological Society of China and China University of Geosciences, Beijing.

YANG, T., 1988. The development of geology in Republican China, 1912 -1937. *In* Bowers, J.Z., Hess, J.W. & Sivin, N. (Eds). *Science and Medicine in Twentieth-Century China: Research and Education.* Center for Chinese Studies, The University of Michigan.

ZHOU, M., 1991. "Internationalism" and vertebrate palaeontology of China. *In* Wang, H., Yang, G. & Yang, J. (Eds): *Interchange of Geoscience Ideas between the East and the West.* China University of Geosciences Press, Beijing.

CHAPTER 2

MAPPING VERTEBRATE PALAEONTOLOGY AT THE TURN OF THE 20TH CENTURY: THEORY, PRACTICE AND PLACES

The significance of the fossil vertebrate record of Central Asia and China at the beginning of the 20th century was shaped by the developments in vertebrate palaeontology that took place during the 19th century, following George Cuvier's first description of extinct vertebrates (Cuvier, 1796). During the same period, a cognitive shift was taking place, according to Laudan (1984, p.55), away from the view that "we should seek to restrict our theories entirely to claims about observable entities and processes"; this shift made possible the development of uniformitarianism and evolutionary theories. Theoretical advances and improvements in collecting, transportation and preparation techniques gradually allowed the exploration and interpretation of faunas collected in areas remote from the European and American scientific centres. As a result, evolutionary theories rooted in the study of the geographical distribution of animals and plants were put forward (Wallace, 1855; Sclater, 1858; Darwin, 1859).

An outline of the state of vertebrate palaeontology at the turn of the 20th century can be obtained from a double perspective, conceptual and bio-bibliographical. Accordingly, the first part of this chapter will sketch the conceptual development of the discipline as a whole and as it concerns itself with major groups: early vertebrates (fish and amphibians), reptiles, birds and mammals (with special emphasis on humans). In the second part of this chapter, a bio-bibliographic analysis of the major contributors to the field of vertebrate palaeontology between 1880 and 1920 will be carried out in order to map the topography of the palaeontological landscape in which these developments were taking place.

2.1 - VERTEBRATE PALAEONTOLOGY IN THE 19TH CENTURY: A CONCEPTUAL VIEW

2.1.1. - Overview

There is general agreement among historians of palaeontology that palaeontology acquired its modern scientific status at the turn of the 19th century. Zittel (1901) recognises four distinct periods in the history of palaeontology and, more generally, geology. His first period, during "the ages of antiquity", started with creation and cosmological myths characterised by a lack of "either exact observation of natural phenomena, or of logical deduction from such observations" (Zittel, *op. cit.*, p.1) and ended with the contributions of Greek and Roman philosophers and thinkers. Among the latter, there was an abundance of speculations about the origin and the development of the Earth. However, Zittel places more value on occasional observations about natural phenomena, including the occurrences of fossils and their interpretation as the remains of animals and plants, although "not the most acute thinker of those cultured peoples had even a shadowy premonition of the value that might appertain to fossils as witnesses of a sequence of events in the history of our earth" (Zittel, *op. cit.*, p.11).

Zittel's second period, from the beginning of the 15th century to the eighteenth century, is dominated by discussions about the nature of fossils: whether fossils were the product of a *vis plastica*, a creative force present in the Earth itself, whether they were "illusory sports of nature" (Zittel, *op. cit.*, p. 14), or whether, as had been recognised by the Greeks and Romans, they were the remains of living organisms. During this second period, an increasing number of illustrated descriptions of 'fossil objects' were published, starting with Conrad Gesner's De Rerum Fossilium, lapidum et gemmarum figuris (Zurich, 1565) and continuing with many others, covering many European localities. According to Zittel (*op. cit.*, p. 19), the notion that fossils might be the remains of extinct living organisms was put forward in 1688 by Robert Hooke, an English physicist and mathematician, who was the first to suggest that they might be used to understand the past history of the Earth.

The transition to Zittel's third period is marked by the publication, in 1778, of Buffon's Epoques de la Nature, in which he attempted to construct a "more reasonable history of the earth" based on all the observations that had been made to date: in it, he argued that long periods of time were needed for the transition from a molten planet to a planet habitable by living organisms, although his calculations had no empirical basis. He also recognised the appearance of successive forms of plant and animal life as well as the gradual migration of mammals away from a single northern land mass which subsequently broke up into the 'Old' and 'New' worlds.

Zittel's third period, his 'Heroic Age of Geology' (and palaeontology), spanned the years between 1790 and 1820. During this period, there appeared a number of general descriptions of fossils by such writers as Blumenbach and von Schlottheim in Germany, Faujas de Saint Fond and Defrance in France, Woodward and Parkinson in England. However, it is among writers on particular fossil groups and regional fossil assemblages that one sees emerging the controversy, which was to frame research in palaeontology during the remainder of the 19th century: the debate between transformism and catastrophism (and the implied fixism) was born from the work on fossil shells by Jean-Baptiste Lamarck and fossil mammals by Cuvier. Lamarck's studies on Tertiary Mollusca in the Paris Basin laid the foundations for his Philosophie Zoologique (Philosophy of Zoology), published in 1809, in which he developed and argued the notion that species change with time as new characters acquired as a result of environmental change are transmitted to the following generation and thus become established. Further evidence for his position could be found in other invertebrate groups which he reviewed in his monumental Histoire Naturelle des Animaux sans Vertèbres (Natural History of Invertebrate Animals) published between 1815 and 1822. Cuvier's work on fossil mammals was revolutionary, and many historians see him as the founding father of both comparative anatomy and vertebrate palaeontology. As a result of this work, Cuvier became convinced that species were immutable (fixed) and that change occurred as a result of catastrophes (or global revolutions), which destroyed some species and produced new ones. According to Zittel (*op. cit.*, p. 135), "It was the creative genius of Cuvier that erected comparative anatomy into an independent science, and defined principles upon which the investigation of fossil vertebrates could be carried out with accuracy.". The principles referred to are the correlation of parts (according to which modification of one organ will have an impact on all other organs) and the subordination of characters (according to which the characters which have a greater influence on the organism as a whole are more important than other, subordinate, characters).

Zittel's fourth period (1820-1900) saw the gradual professionalisation and institutionalisation of palaeontology (and geology) in Europe and the spread of active geological and palaeontological research to North America. According to Rudwick (1976), the first, pre-Darwin, half of the 19th century was, dominated by a double project: a stratigraphical project aiming at working out the relative ages of rock strata, and a biological project, attempting to use the fossil record to explain the present distribution of flora and fauna. In his 1796 paper, Cuvier presented the first detailed evidence of the occurrence of extinctions, based on a comparative study of living and fossil elephants. The question of the fate of extinct species acquired paramount importance and, in a later paper, Cuvier (1801) proposed three alternatives: extinction, evolution and migration. Cuvier rejected the migration hypothesis, especially for large terrestrial vertebrates, as there was no unexplored part of the globe where they could hide, and the evolution hypothesis on the basis of his fixist understanding of biology.

These three concepts (extinction, evolution and migration) were to frame research in vertebrate palaeontology until the present day. Cuvier's further research led to the conclusion that the history of life had been punctuated by several revolutions (catastrophes) leading to faunal changes, and he saw that the main task of geological research was to elucidate the timing, possible causes and effects of these revolutions. As a result of Cuvier's and Alexandre Brongniart's work in the region around Paris (Cuvier & Brongniart, 1808) and the studies of William Smith in England (Smith, 1816 – 1819), fossils began to be used in the correlation of strata and the reconstruction of palaeoenvironments.

During the same period, the work of Etienne Geoffroy St Hilaire who had been influenced by Lamarck's concept of continual and "progressive" organic change, presented a different interpretation of the observed faunal changes through time: he suggested that these changes were gradual and resulted from adaptation to environmental changes. These, in turn, were directional, according to Buffon's model of the gradual cooling of the globe, which had recently been strengthened by Fourier's calculations of heat flow in a cooling sphere. This model allowed for the gradual increase in the diversity and complexity of organisms in response to gradual global cooling through time.

Neither of these two interpretations provided an answer to the important question of the emergence of new species, and this was probably because most of the fossil evidence and research centred on the European record (with the exception of the giant fossil ground-sloth from Paraguay, *Megatherium*, the American fossil *Mastodon* studied by Cuvier, and the mummified remains of animals from Egypt studied by Geoffroy St Hilaire).

1830 - 1850: From Lyell to Darwin

The following two decades saw a shift of activity from France to England where the Geological Society of London became a prominent voice in the international community, replacing the Paris Museum in the debate about the nature of changes in Earth history. One of the highlights in this debate was the publication in 1830-1833 of Lyell's <u>Principles of Geology</u> in which he noted two fundamental principles:

(1) that the processes which acted in the past are the same as those acting in the present

(2) that these processes "never acted with different degrees of energy from that which they now exert".

This position is close to Hutton's uniformitarianism and does not allow for the possibility of occasional events of greater intensity, such as Cuvier's revolutions, nor for any decrease in the scale of mountain-building and volcanic activity resulting from the gradual cooling of the Earth as postulated by Lamarck and Geoffroy St Hilaire. Lyell's position was actualistic (the Earth's past can be explained in terms of natural processes observable at present *i.e.*, the present is a key to the past) and progressionistic (progressively higher life forms have developed on Earth). It implied a vast geologic time scale, a steady-state Earth and slow and steady change (gradualism). According to this view, the piecemeal extinction of species is part of "the regular course of nature". However, Lyell was not able to provide an actualistic answer to the problem of the emergence of new species, let alone whole new floras and faunas.

At about the same time, Roderick Murchison and Adam Sedgwick were in the process of defining the divisions of the Palaeozoic era, based on their own work in England and other places in Europe, but also on the work of a growing number of palaeontologists and geologists who were making observations all over the world. This resulted in the recognition of the Cambrian, Silurian, Devonian, Carboniferous and Permian periods based on fossil content, and, most importantly, on the recognition that the history of life had been directional and progressive, from the Silurian with no land plants and no vertebrates to the appearance of fishes during the Devonian, of land plants during the Carboniferous and of reptiles during the Permian. This was very much contrary to Lyell's central steady-state theory, although the gradual character of this progression agreed with his actualistic stance. This work had important consequences, because of the conceptual shift from extinction to evolution.

1850-1870: The evolution debate

The publication of Charles Darwin's <u>On the Origin of Species</u> in 1859 has its biogeographical sources in his observations during the voyage of the Beagle 20 years earlier: his conception of the centrality of the species concept was subsequently confirmed by 8 years of work on barnacles, fossil and living. The book proposed natural selection as a mechanism for trans-specific evolution and examined the implications for the fossil record, biogeography, comparative anatomy and embryology. Reactions to <u>On the Origin of Species</u> in the palaeontological community were mixed. The main problems raised were:

1. the imperfection of the fossil record, which did not provide any evidence for gradual transition (such as intermediate forms) between major groups, and
2. the problem of the recently discovered Palaeozoic life forms, which were found to be quite complex.

Richard Owen's opposition to Darwin's theory centred on the mechanism proposed rather than the idea of evolution as such. According to MacLeod (1965, pp. 278-279):

> Philosophically, as we have seen, Owen combined the attributes of an Aristotelian systematist, a Cuvierian teleologist, an Okenian idealist, and a Broad Church theist. His training in taxonomy showed him the vast interrelationships among living things; his teleological inclination convinced him of a powerful Designing Hand at work in the animal frame; his idealism gave him a basis for relating his systematic knowledge and the principles of functional adaptation; and his religious belief strengthened him in the faith that no simple mechanical concept could account for the manifold variations existing around him. Thus, he was a fairly willing convert to the general notion of evolution, and tended to understand it as a developing process in the mind of God, a process which, according to Divine Will, might be made manifest in a gradual progression of living forms; by the same token, however, he was a doctrinal opponent of Darwinian natural selection.

Recent research reviewed by Padian (1997) has put into perspective the relationship between Darwin and Owen and highlighted the collaboration between the two men, at least before the publication of On the origin of species in 1859. The difference between Darwin's naturalistic and materialistic approach and Owen's more transcendental one led to the latter's rejection of natural selection as a mechanism or a law "by which the Prime Mover worked" (Padian, *ibid.*, p. 449).

According to Rudwick (*op. cit.*, p. 242), Charles Lyell finally came out in favour of Darwin's evolutionary interpretation of the history of life on Earth in his Antiquity of Man (1863) where he attempted to sketch an evolutionary history of man based on the developing, although still fragmentary, record. These reactions had an important role in framing the direction of the subsequent palaeontological research programme. The fossil record might be too incomplete to show trans-specific changes, too poorly known in its oldest parts to trace the origin of phyla, but seemed adequate to trace familial and generic relationships.

Albert Gaudry took part in an expedition, sponsored by the French Academy of Sciences, to the Miocene deposits of Pikermi in Greece between 1855 and 1860. This provided the material that enabled the construction of phylogenetic trees (of the horse family among others) and highlighted the importance of intraspecific variation (Gaudry, 1862 – 1867). Thomas H. Huxley, on the strength of these results, even anticipated the existence of intermediate forms at higher taxonomic level (Rudwick, *ibid.*, p. 249): this anticipation was fulfilled by the discovery of *Archaeopteryx* (a reptile-like bird) in 1861 in the Solnhofen quarries of Bavaria.

Further evolutionary interpretation of the fossil record depended, then, on the accumulation of evidence from the fossil record and the solution of the following problems: the question of inter-specific evolution, and at a higher taxonomic level, the origin of the major groups of organisms. It also resulted in a shift from a dominantly stratigraphical to a more biological approach to vertebrate palaeontology.

1870 - 1910: Biogeography, tectonics and the fossil record

According to Browne (1983, p. 222), biogeography or the study of the geographical distribution of organisms, after a long association with geography, geology and natural history (from which it borrowed methods and interpretations), gradually evolved its own frame of reference. Two main objectives underpinned this framework: one, favoured by zoologists and botanists, concerned the distribution and relations of groups of organisms, while the other (not surprisingly, favoured by geologists and palaeontologists) focused on the history of distribution of organisms and its implications for the history of the Earth. As a result of the multidisciplinary nature of this discipline, population statistics were successfully integrated with a directional model for the history of the Earth and stratigraphical correlation, culminating in the work of Wallace and Darwin who "studied the natural world as a combination of both history and statistics, processes and patterns". Post- Darwinian biogeography, according to Greene (1985) was a synthesis between geology and palaeontology, based on the contraction hypothesis (that the main geological features of the Earth such as mountain ranges and the distribution of continents and oceans could be explained by the gradual contraction of the Earth's surface as it cooled). This directional interpretation guided the first 'golden age' of palaeobiogeography during which, the work of Eduard Suess (*The Face of the Earth*, 1904 – 1909, originally published in German in 1883 – 1904 as Das Antlitz der Erde), Louis De Launay (*La Science Géologique*, 1913) and Thomas Chamberlin & Rollin Salisbury (*Geology*, 1905-1907) highlighted the "tectonic control of marine transgression cycles, of climate and climate change, of faunal and floral distributions and alterations through time" (Greene, *ibid.*, p. 96). The subsequent emergence of alternative hypotheses, such as continental drift and the conflicting interpretation characterised by continental permanence, vertical tectonics and occasional land bridges, created a tension which affected the work on the origin and distribution of species by William D. Matthew, Henry F. Osborn and Amadeus W. Grabau. All of these workers became interested in the Central Asiatic fossil vertebrate record as the potential cradle of mammalian evolution.

2.1.2 - The Fossil Record of Major Vertebrate Groups

Fish

In his review of the history of research on fossil fishes, Janvier (1996) clearly establishes the importance of amateur palaeontologists in the early work on Palaeozoic fishes that took place in Scotland in the first half of the 19th century. Their work was encouraged by Adam Sedgwick and Sir Roderick Murchison, who had embarked on a geological survey of Scotland and hoped to use the fossils for dating rocks. Among these early researchers, we find Hugh Miller, a stonemason and writer, and John Grant Malcolmson, an army surgeon whose drawings of fossils led to the recognition by Agassiz of the first placoderms and, more specifically, *Coccosteus*. Lady Gordon Cumming and her daughter collected and drew many of the fossil fishes found in a local quarry, and they, too, provided Agassiz with more material.

Louis Agassiz (1807-1873) is recognised as the founding father of palaeoichthyology and, according to Gaudant (1980), his pioneering work on fossil fishes, which he published in his Recherches sur les Poissons Fossiles (Researches on Fossil Fishes, 1833-1844) and Monographie des Poissons Fossiles des Vieux Grès Rouges (Monograph on Fossil Fishes in the Old Red Sandstone, 1844-1845), was made possible by his visits to many European museums and his contacts with major fossil fish collectors. His work was inspired by Cuvier's comparative approach. Agassiz compared the anatomy of fossil fish with that of living fish and studied not only their skeletons, but also their scales, which he used in the new classification of fishes that he proposed. Agassiz was the first to recognise the nature of acanthodian spines, and he defined several acanthodian genera. Agassiz proposed that palaeoichthyology be applied to solve stratigraphic, palaeogeographical, palaeoclimatic and palaeoecological problems, but his conceptual framework was characterised by a resistance to transformist ideas. He also supported an embryological model of vertebrate classification whereby the Old Red Sandstone Devonian fishes represented an "embryonic and synthetic stage", which had the potential to produce more recent fishes as well as reptiles, birds and mammals, and furthermore suggested that this succession was the expression of a divine plan. As a result of the Swiss revolution against Prussia (1848), the Collège of Neuchatel, to which Agassiz had been attached, was dismantled, and he remained at Harvard where he had been temporarily teaching. His interests subsequently switched to modern fishes and the study of glaciers.

According to Janvier (1996), the Scottish fossil fish collections were also put to good comparative use by a Russian palaeontologist in St Petersburg, Christian Heinrich Pander. Pander described, in a series of monographs published in the 1850's, the fish fossil remains collected from Silurian and Devonian rocks in the Baltic Provinces of Russia (Estonia, Latvia and Lithuania), which thus became a new focus of early palaeoichthyological research.

Back in Scotland, Ramsay Heatley Traquair (1840-1913), based at the Royal Scottish Museum in Edinburgh, was making extensive contributions to the understanding of the early fossil fish record of Scotland, by studying Carboniferous actinopterygians and discovering Silurian jawless fish. He also described some German Devonian material from the Hunsruck slates, such as the heterostracan *Drepanaspis*.

Meanwhile, in Great Britain, under the influence of the evolutionary debate taking place in response to Darwin's Origin of the Species, Thomas H. Huxley and E. Ray Lankaster began to study Palaeozoic fishes in a more "zoological manner, *i.e.* with regard to their relationships to extant fishes" (Janvier, *ibid.*, p. 315). The subsequent work of Bashford Dean on arthrodires in the U.S. and, later, of Erik Stensiö in Sweden was built on a similar foundation. Stensio realised that the internal anatomy of fishes, which he explored through a variety of new anatomical techniques, would provide more insight into the relationship of fossil and living fishes.

Amphibians

According to Lehman (1955), the group Amphibia was first named by Carl Linnaeus in his Systema Naturae (1758): this group then included both reptiles and amphibians. De Blainville, in 1816, separated reptiles and what are now considered amphibians and raised both groups to the level of class. The first fossil amphibian was recovered in 1726: this giant salamander (*Andrias scheuchzeri* Tschudi), collected from the Upper Miocene rocks of Switzerland, was first interpreted as the diluvial remains of a man and later identified as a salamander by Cuvier. The first labyrinthodont (a stegocephalian) was discovered in 1824. Because of the infolded dentine in their teeth, Owen (1842b and c) proposed to call labyrinthodonts all the animals with a similar dental structure (Zittel, 1901), and this name is still in use today even though it is possibly a polyphyletic group. Many of the first-described reptiles have a generic name ending in -saurus as they were interpreted as reptiles. Owen (1866) was the first to publish a classification which squarely classified reptiles with extant and extinct batrachians (Lehman, 1955) and, subsequently, Edward

D. Cope and Zittel developed a classification of amphibians based on the structure of vertebrae. A problem of interest to early amphibian research was that of the origin of amphibians. In his review of the question, Gregory (1915) concluded that although there was no evidence in the fossil record of intermediate forms between fishes and amphibians, comparative anatomy suggested that they shared a common ancestor, and rhipidistian crossopterygians were the most likely candidate.

Reptiles

We have seen above that reptiles had been originally placed by Linnaeus in the class of Amphibia, and raised later to the level of an independent class, Reptilia, by Henri De Blainville in 1816. According to J. Piveteau (1955), subsequent studies by R. Owen, E.D. Cope, H.G. Seeley and T.H. Huxley led to establishment by H.F. Osborn in 1903 of two major divisions according to the structure of the temporal region: the Synapsida (one single temporal fenestra, mammalian affinities) and the Diapsida (two temporal fenestrae, avian affinities). E.S. Goodrich (1916), on the basis of a combination of characters present in extant reptiles (heart and circulatory system) and extinct ones (morphology of the fifth metatarsal), divided reptiles into Sauropsida (with avian affinities) and the Theropsida (with mammalian affinities). The structure of the temporal region did, however, become central to the modern classification of reptiles, which, according to Carroll (1988), contains the following groups:

- anapsids (with no temporal opening): *e.g.* turtles
- synapsids (with a single temporal fenestra): *e.g.* mammal-like reptiles
- diapsids (with two fenestrae): *e.g.* dinosaurs, pterosaurs and all living reptiles other than turtles
- euryapsids (or parapsids) characterised by a single opening thought to be derived from the diapsid condition: Mesozoic marine reptiles such as plesiosaurs and ichthyosaurs show this condition.

The discovery and exploration of dinosaurs at the turn of the twentieth century had a major impact on the development of vertebrate palaeontology, field techniques and the finding of new fossil fields (Breithaupt, 1997). But, early discoveries date back to 1677: the first report can be found in Robert Plot's Natural History of Oxfordshire according to which a dinosaur (*Megalosaurus*) bone discovered in Cornwall was interpreted as the bone of an elephant (Sarjeant, 1997). It was subsequently illustrated, upside down, in Richard Brookes' Natural History of Waters, Earths, Stones, Fossils and Minerals and named *Scrotum humanum* (because of the similarity in morphology). The rediscovery of this name by Beverley Halstead led to some mischievous correspondence with the International Commission of Zoological Nomenclature to ensure that this, the first recorded name for a dinosaur, become a 'nomen oblitum' (Halstead & Sarjeant, 1995).

The first scientific description of dinosaur bones took place in England. In 1824, Buckland described, for the Geological Society, the teeth and part of the lower jaw of *Megalosaurus*, a theropod found in the Middle Jurassic of Oxfordshire (Buckland, 1824). One year later, Gideon Mantell presented to the Royal Society of London the fossil teeth of a giant herbivorous reptile, which he named *Iguanodon* after their similarities to the teeth of a living iguana (Mantell, 1825). In 1841, Richard Owen described the first sauropod dinosaur, *Cetiosaurus*, based on some bones from the Mantell collection as well as others (Owen, 1841) and set up the name 'Dinosauria' to describe this group of saurian reptiles (Owen, 1842c). Dinosaurs were long thought to be exclusively quadrupedal since the fragmentary nature of the remains did not indicate otherwise. Evidence from the U.S.A. was going to change this: in 1858, Joseph Leidy (Leidy, 1858) presented a description of a herbivorous dinosaur, *Hadrosaurus*, at the Philadelphia Academy of Sciences. The size difference between the forelimbs and the hind limbs suggested that this dinosaur was bipedal and this interpretation was gradually extended to other groups (Breithaupt, *ibid.*).

Meanwhile, in France, discoveries of dinosaurian fossils were made in several regions (Normandy, eastern France, Provence and the Pyrenées) and in strata of Late Triassic to Late Cretaceous age. Even dinosaur eggs were found (in Provence and the Pyrenées), but they were not recognised and had been forgotten by the time of the Gobi Desert finds in the 1920's. However, according to Buffetaut, Cuny & Le Loeuff (1995), the importance of this fossil record was neglected, as a large number of finds were made by local collectors and remained in private collections, which were lost or destroyed. Some of this material did find its way into the collections of regional museums (especially in Normandy), but the leading French vertebrate palaeontologists of the time such as Albert Gaudry and Charles Depéret were mostly concerned with the use of dinosaurs for attractive displays or as illustrations for the evolutionary processes in which they were interested. The fragmentary nature of most of the French material, especially compared with the *Iguanodon* find in Bernissart (Belgium) or the complete skeletons from America, resulted in a lack of active exploration of promising sites in France and the French colonies.

The Bernissart discovery was made in a coal mine in 1878 and over a period of three years, the bones amounting to nearly 40 skeletons were recovered. According to Weishampel *et al.* (1990), this extraordinary assemblage was first interpreted as the result of a catastrophic kill before being re-interpreted in light of new evidence as accretional in nature.

The 'first golden period' of dinosaur discoveries, as Breithaupt (*ibid.*) called it, started with the collection by Ferdinand Vandiveer Hayden and the description by Joseph Leidy, in 1856, of dinosaur remains from the American West. Between 1870 and the turn of the century, in the course of the surveys associated with the opening up of the West and the building of railroads, teams of professional collectors sent fossil bones to the rival palaeontologists, Edward Drinker Cope and Othniel C. Marsh, who described and named many dinosaurs such as *Allosaurus, Apatosaurus, Camptosaurus, Diplodocus, Stegosaurus* and *Triceratops* (Marsh) and *Camarosaurus* and *Coelophysis* (Cope). The majority of these came from the Upper Jurassic Morrison Formation, which is found in Wyoming and Colorado. According to Breithaupt (*ibid.*), the quality and the diversity of the dinosaur remains found there led to much better and more detailed knowledge of dinosaurs as a group and spurred subsequent worldwide expeditions. Discoveries were made in Canada along the Red Deer River Valley by Joseph Tyrrell in 1884 (*Albertosaurus*) and, in 1910, by Barnum Brown, in Tanzania (then a German colony), where scientists from the Berlin Museum of Natural History assisted by native Africans recovered several sauropod skeletons (*Dicraesaurus* and *Brachiosaurus*) and the stegosaur *Kentrosaurus* from the Late Jurassic Tendaguru Beds (Norman, 1985). Explorations into the Gobi Desert and China, which are the focus of this thesis, would follow later, and, more recently, the fossil record of dinosaurs in South America and Australia came to light (Bonaparte, 1969; Molnar, 1982; Rich & Rich, 1989; Thulborn, 1970). Marsh (1896) surveyed the fossil record of dinosaurs available at the time (20% of the modern record) and highlighted the importance of the North American record in establishing a framework for a classification system and bringing to light the diversity characterising the group (Weishampel *et al.*, *ibid.*).

Birds

The fossil record of birds, although relatively poor (because of the absence of teeth except in the more primitive groups, the lightness of the skeletal elements and their lifestyle), has provided the best example of the transitional nature of evolution between higher taxa. In 1861, the discovery of *Archaeopteryx* (a mosaic of reptilian and avian characters, Jurassic in age) in the limestone quarries of Solnhofen, and its description by Richard Owen (1863) provided the evidence expected by the supporters of Darwin's theory of evolution such as T.H. Huxley, who had predicted the existence of intermediate forms at higher taxonomic level (Huxley, 1868).

Earlier studies of the fossil record of birds had been carried out by Cuvier, and more extensively by Alphonse Milne-Edwards who, in his review of the fossil birds of France (1868-1872) established the osteological basis for the study of birds (Zittel, 1901). In 1875, Marsh described the first Cretaceous toothed birds from Kansas, U.S.A., while the first fossil moas from New Zealand had been described by Owen in the 1850's. The first exhaustive classification of birds, both living and fossil, was published by M. Fürbringer in 1888. An unexpected spin-off of the study of the geographical distribution of birds was the development of a scientific framework for biogeography (Evans, 1899): Sclater (1858) divided the world into 6 regions on the basis of bird distribution: the Palaearctic, Ethiopian, Indian and Australian regions, constituting the Old

World, and the Nearctic and Neotropical regions, constituting the New World. This classification was adopted and used by Wallace in his studies on the geographic distribution of animals.

Mammals

The fossil record of mammals was the main focus of Cuvier's studies, which established the reality of extinction and laid down the principles of comparative anatomy which, together, led to the development of vertebrate palaeontology as a scientific discipline. Knowledge of the mammalian fossil record, like that of the dinosaurian record expanded rapidly during the 19th century, for taphonomic reasons (more abundant and more accessible fossil remains) and cultural reasons (curiosity for the different, in the case of dinosaurs and interest in the familiar, in the case of mammals). The mammalian fossil record, especially the Tertiary record, lent itself more readily to studies of evolutionary processes, which interested many leading palaeontologists of the day (Buffetaut *et al.*, 1995). Zittel's account (1901) contrasts the more anatomical approach taken by Cuvier and others such as that of Lydekker, and the more evolutionary approach of Gaudry (a supporter of evolution by continuous divine creation), Huxley, Rutimeyer, Cope and Marsh, who based their support for Darwin's theory of evolution on evidence provided by the palaeomammalian fossil record.

Richard Lydekker's contributions to vertebrate palaeontology fall into two categories related to the two phases of his career. During his time of service in the Geological Survey of India, between 1874 and 1881, he made extensive studies of the Siwalik Hills (based on and extending Falconer's work in the 1840's). After his appointment to the British Museum (Natural History), he took charge of the mammalian section of the British Museum and wrote an extensive <u>Catalogue of Fossil Mammalia in the British Museum (Natural History)</u> (1885-1887). He also became interested in the biogeography of mammals (1896), which was becoming a topic of utmost interest at the turn of the century.

Ludwig Rutimeyer (1825-1895) is regarded by Zittel (1901, p. 421) as "one of the most celebrated palaeontologists in the domain of fossil Mammalia".

He is credited with the first serious attempt, after Darwin's On the Origin of Species, to interpret fossil mammals as parts of evolutionary lineages by showing the gradual change in their dentition. He also became interested in the biogeography of mammals: he studied the relationship between New World and Old World mammals and proposed a bi-polar theory of mammalian evolution according to which both the northern hemisphere and Africa had been centres of origin for mammalian evolution. Other workers, such as W. Haacke and J.L. Wortman supported a north polar theory while the Argentinian Florentino Ameghino held a south polar theory (Osborn, 1910).

In North America, Cope and Marsh's explorations in the western part of the continent, uncovered mammals as well as the reptiles mentioned earlier. Marsh based his outline of the evolution of the horse in North America on a series of specimens from the Eocene to the Pleistocene. He also worked on Mesozoic mammals as well as some more recent large-horned mammals, such as the uintatheres and the brontotheres. Cope's contributions were more theoretical and he became interested in mammalian taxonomy as well as evolutionary theory: one of his claims to fame is as a proponent of neo-Lamarckism.

In England, both Huxley and Owen, on opposite sides of the divide created by the debate around Darwin's On the Origin of Species, made wide-ranging contributions to mammalian palaeontology, both theoretical and taxonomic: T.H. Huxley, 'Darwin's bulldog', like Cope and Marsh in the U.S. and Gaudry in France, found, in the study of fossil mammals, illustrations of Darwin's central idea of "divergent evolution from primordial forms" (Osborn, 1910, p. 6). Huxley is also credited by Osborn (*ibid.*, p.7) with the development of a "method of palaeontology, or the modes of examining and testing facts, of synthesis and analysis". He was also the first to attempt the prediction of what the primitive or 'stem' member of a group would look like: he divided characters into advanced and primitive and predicted that a stem form could be reconstructed from primitive characters. This mind-game became quite popular (and an antidote as well as a complement to the frustrations of fieldwork). Huxley was interested in the palaeoecological as well as the biogeographical dimensions of the fossil record. In 1870, he supported the theory for the existence of a southern land bridge between Australia, New Zealand and South merica in order to account for the observed distribution of mammals and, in 1880, he put forward the hypothesis that the primitive marsupials had an arboreal lifestyle. As for Owen, his prominent position at the British Museum (Natural History) made him the favoured recipient of fossils collected abroad and the describer of many Australasian, South American and Asiatic, as well as British fossil mammals.

The Special Case of Fossil Man

Meanwhile, interest in the fossil record of humans was being fuelled by the discovery in the 1840's of stone implements in the Quaternary terraces of the Somme River Valley in northern France (Boucher de Perthes, 1847) and that, in 1856 of the Neanderthal remains in the Neander River valley, near Dusseldorf, in Germany. Jacques Boucher de Perthes's discovery was confirmed in 1859 by the English geologist Joseph Prestwich (Prestwich 1859 and 1860) who, in a communication to the Royal Society, showed that the stone implements and the associated bony remains of extinct mammals had been extracted from undisturbed gravel deposits which "had been laid down during a period anterior to the modern geological period" (Spencer, 1990, p. 2).

This took place in the context of a debate about the antiquity of man where, in the near absence of actual human fossil remains, workers had used stone implements to establish a correlation with geological events (glaciation events). In 1859, John Evans established the difference between the kind of implements found by Boucher de Perthes, which had "merely been roughly chipped out of flint, and in no case ground" and the more modern tools attributed to pre-Roman (Celtic) dwellers, which did "show traces of having been ground and polished " (quoted in Spencer, 1990, p.8; from a letter from Evans to Prestwich quoted in Prestwich, 1861). In 1865, John Lubbock coined the terms "Palaeolithic" and "Neolithic" to describe the former and the latter, respectively (Lubbock, 1865). Mortillet, a fervent Darwinist keen to show the connection between material progress and the evolution of man, subdivided the Palaeolithic into 5 stages according to stone tool types. In 1883, he correlated these with glaciation events and put forward the concept of an Eolithic (Dawn Stone Age), predating the Palaeolithic and characterised by the very crude implements produced by the Tertiary ancestor of humans.

Meanwhile, the recognition that the Neander Valley human fossils had a very distinctive morphology characterised by thick limb bones and prominent brow ridges led to a lively debate between evolutionists and anti-evolutionists, the former interpreting them as evidence for an early stage of human evolution, while the latter believed they were deformities resulting from a pathological condition. In 1864, William King created a new species *Homo neanderthalensis*, the first (of many) separate *Homo* species after *H. sapiens*. The subsequent discovery of more Neanderthal remains from Gibraltar (1864), Spy (in Belgium, 1887) and La Chapelle-aux-Saints (in France, 1908) led to the recognition that *H. neanderthalensis* had populated extensive tracts of Europe (Reader, 1981).

In 1868, Ernst Haeckel published <u>Natürliche Schöpfungsgeschichte</u> (translated in 1876 as <u>The History of Creation</u>), in which he constructed one of the first trees of life where he represented the evolutionary relationships of the twenty stages of life, beginning with the primitive Protozoa and ending with anthropoid apes such as the chimpanzees and gorillas. Because of the presence in humans of the attribute of speech and its absence in anthropoid apes, Haeckel speculated that there must have existed a speechless ape-like human form, a "missing link" which he proposed to call *Pithecanthropus*. Haeckel postulated that this human ancestor would have originated in Lemuria, a continent which, on the basis of floral and faunal distributions, was thought to have once extended across the Indian Ocean, from Africa to Indonesia including India and Madagascar. According to Reader (1981), Haeckel's ideas inspired a young anatomist with an interest in palaeontology, Eugene Dubois, to sign on with the Dutch East Indian Army and sail for the East Indies (now Indonesia) in order to find remains of the "missing link". In the course of a palaeontological survey in Java, in 1891, Dubois recovered a human skull cap and tooth near Trinil (in southeast Java), in the Kendeng deposits which had been dated Pliocene on the basis of the similarity between its fossil vertebrate fauna and that of the Siwalik deposits in India. This discovery was followed, in

1892, by that of a femur not far from and in the same bed as the skull and tooth. On the basis on these discoveries, Dubois erected the new species *Anthropopithecus erectus* in 1892, which he later revised to *Pithecanthropus erectus* in 1894 on the basis of the human-like appearance of the bones. Dubois's thesis that he had discovered the missing link between man and ape led to heated arguments at several scientific meetings in the following years; although his discoveries were very important, Dubois's interpretation was believed to be flawed by most of his contemporaries. As a result, upon his return to Holland, Dubois restricted access to these fossils until the early 1920's when examination by the anthropologists A. Hrdlicka (from the Smithsonian Institution) and H.H. Mc Gregor (from Columbia University) confirmed that the Java fossils belonged to a human ancestor, not to a missing link between ape and man. A subsequent comparative study of *Pithecanthropus* and *Sinanthropus* (Peking Man) by Koenigswald and Weidenreich (1936) concluded:

> Considered from the general point of view of human evolution, *Pithecanthropus and Sinanthropus*, the two representatives of the Prehominid stage are related to each other in the same way as two different races of present mankind, which may also display certain variations in the degree of their advancement.

The next episode in the history of palaeoanthropology, the discovery of the Piltdown human fossils, should not warrant a dominant place in this narrative since they were later proved to have been fabricated. However, the participation in these events of Pierre Teilhard de Chardin (one of the main participants in the early history of vertebrate palaeontology in China), the historical context in which the Piltdown discovery took place and the philosophical implications for palaeoanthropological research make it a very interesting episode. The Piltdown finds took place at a time when debate about the evolutionary development of man was concerned with the relative timing of the appearance of three human characteristics: large brain, erect posture and the ability to speak.

According to Reader (*ibid.*), Arthur Keith, an anatomist, favoured the early appearance of erect posture, based on his comparative studies of the anatomy of humans and apes. On the contrary, Grafton Elliot Smith, a neuroanatomist, held the view that it was the earlier development of the brain which allowed the primates to adopt an arboreal lifestyle and, subsequently, an erect posture. Charles Dawson, a solicitor, first became interested in the Piltdown site, some time at the turn of the century, during his appointment as Steward of the Barckham Manor (on which estate the site, a gravel pit, is located) (Spencer, 1990, p. 31). The discoveries, in 1911, of a skull fragment and hippopotamus tooth were subsequently reported to Arthur Smith Woodward, the Keeper of Geology at the British Museum (Natural History), since Dawson was an honorary collector for the Museum. In June 1912, Woodward, Dawson and Teilhard de Chardin, an associate of Dawson's in matters palaeontological, went to examine the site and, as a result, Dawson and Woodward decided to work on the pit during the summer of 1912, in the course of which they found three human parietal fragments and, in close proximity to the parietal fragments, an ape-like mandible bearing two molars that looked decidedly more human than ape-like. The subsequent reconstruction by Woodward showed some remarkable results. According to Spencer, 1990 (p. 41):

> On reaching this stage, under Woodward's careful direction, the skull and mandible were restored and fitted by Frank Barlow, a senior preparator at the British Museum (Natural History). The resulting form was quite remarkable - a curious blend of ape and human features. The assembled braincase, although distinguished by its low capacity (estimated to be 1070 cc), its globular appearance and more particularly its steep smooth-browed forehead was, as Woodward confessed, surprisingly modern and scarcely a basis for removing it from the human genus. But when the jaw was added and the face restored, the Piltdown skull underwent a remarkable transformation to a form of humanity quite distinct from that of any of the known ancient and modern forms of *Homo*.

The Piltdown skull, dated Early Pleistocene, possibly Pliocene after the associated fossil fauna and flint artefacts, was presented to the Geological Society of London on December 18th, 1912. This presentation was followed by a heated debate fuelled partly by the absence of critical anatomical features that would have conclusively proved that the skull and the jaw did in fact belong to the same individual, and also by differing philosophical positions about the antiquity of man.

Subsequent explorations by Dawson were rewarded by the discovery, in 1915, of a forehead fragment still attached to a portion of the eyebrow ridge and the root of the nose, a molar and another piece of the skull. These discoveries were presented, in 1917, to the Geological Society and were argued to belong, like the earlier finds, to a new species of early man named *Eoanthropus dawsoni*.

However, during the 1920's and 1930's, new fossil evidence was turning up that made the association of a large brain and an ape-like jaw more and more unlikely and the validity of the Piltdown find thus became challenged on palaeontological, anatomical and geological grounds.

In 1950, Kenneth Oakley published the results of a fluorine test on both the 'human' fossils and the associated fossil fauna (Oakley and Hoskins, 1950), which showed that the former were much younger than the latter. Subsequent examination of the wear pattern on the teeth by Joseph Weiner and Professor Le Gros Clark revealed that the Piltdown remains were indeed forgeries, thus opening a debate about the identity and the motivations of the forger(s), which lasted almost 40 years. Spencer's book (1990), based on Ian Langham's research, conclusively argued that Charles Dawson and Arthur Keith had collaborated on this forgery for a combination of reasons ranging from a desire on Keith's part to corroborate his ideas on the antiquity of man to a more mundane desire, on Dawson's part, to become a Fellow of the Royal Society.

The next major palaeoanthropological discovery moves the scene to Africa: three years after the description of *Homo rhodesiensis*, a more modern form of Neanderthal man from Rhodesia (now Zambia), by A.S. Woodward in 1921 (Tattersall, 1995), Raymond Dart, a student, and fellow Australian, of Grafton Elliot Smith, was handed the fossil brain cast and facial bones of an infant hominid, which had been collected in the Taung Quarry in South Africa. Raymond Dart had just been appointed a Professor of Anatomy at the Witwatersrand University, where he proceeded to describe the new find in relative isolation. On the basis of skull proportions, dentition and mandible characteristics, the position of the foramen magnum (suggesting an erect posture) and brain anatomy as revealed in the endocranial cast, Dart (1925, p. 198) concluded that:

> it represents a fossil group distinctly advanced beyond living anthropoids in those dominantly human characters of facial and dental recession on one hand, and improved quality of the brain on the other. Unlike *Pithecanthropus*, it does not represent an ape-like man, a caricature of precocious hominid failure, but a creature well advanced beyond modern anthropoids in just those characters, facial and cerebral, which are to be anticipated in an extinct link between man and its simian ancestor. At the same time, it is equally evident that a creature with anthropoid brain capacity and lacking the distinctive, localised temporal expansions which appear to be concomitant with and necessary to articulate man, is no true man. It is therefore logically regarded as a man-like ape.

On this basis, he created a new family Homo-simiadae and a new genus and species *Australopithecus africanus* in acknowledgement of the Darwinian claim that "Africa would prove to be the cradle of mankind" (Dart, *ibid.*).

Dart's claim generated a great deal of press coverage which, along with the lack of availability of casts, may have played a role in the rather reserved reception from the palaeoanthropological establishment of the day (Keith, Smith, Woodward & Duckworth, 1925). When Dart finally came to London with his original material, interest had shifted from the Taung specimen. The search for the cradle of mankind had returned to Asia, more specifically China and central Asia, where the climatic change that was thought to be critical to the evolutionary development of humankind may have taken place as a long-term result of the uplift of the Himalayas and where the fossil remains of Peking Man were being excavated at Zhoukoudian, near Beijing (Tattersall, 1995).

2.1.3 - The fossil vertebrate record of Central Asia and China and its relevance to the international palaeontological community

Henry Fairfield Osborn and The Age of Mammals

During the last quarter of the nineteenth century, the past and present biogeographical distribution of the major animal groups had become a central and accessible question to palaeontologists as the fossil record for most continents improved. However, a cursory look at the bibliography of Osborn's seminal review of the mammalian faunas of the world (Osborn, 1910) shows that, in the early twentieth century, the record was still heavily biased towards Europe and the Americas. The Asiatic record was only marginally known. According to Osborn (1910, p. 65):

> The source of the world's mammals, the great homes, centres, or continents from which the orders evolved and took on their distinctive form, still remains as one of the great problems of the Age of Mammals which has not been thoroughly worked out. The solution turns upon palaeogeography, or the past relations of the continents and islands to each other, but many paleogeographic problems in turn appeal to the past and present distribution of animals and plants.

Consequently, the permanency or mobility of continental arrangements would influence the understanding of the relationships between the observed groups in different regions of the globe. Osborn's position on this question was very conservative: he rejected (Osborn, *ibid.*, p. 80), on the grounds of 'imperfect record', the existence of an Antarctic land connection between Australia and South America, even though it appears on a Late Cretaceous map of the world shown earlier (Osborn, *ibid.*, p. 64) and based on W.D. Matthew's previous work. He suggested a northern source for most of the fauna and flora in the Southern Hemisphere (Osborn, *ibid.* p.67) and recognised the importance of the Ethiopian Region (eastern Africa) as the source of northward migration of mammals (Osborn, *ibid.*, p. 71). He accepted the existence of intermittent land bridges between Asia and North America (across the Bering Strait in the North Pacific), and between North and South America, as evidenced by episodes of similarity and separation between the respective faunas of these continents at different stages.

One of the most important conclusions drawn by Osborn from the known distribution of fossil mammalian faunas and his understanding of the past distribution of continents was that there was a close kinship between the faunas of the Holarctic region (which includes North America, Asia and Europe). The pre-Miocene mammalian faunas in North America, Asia and

Europe were very similar, with the exception of the faunal elements contributed by Africa to Europe and by South America to North America.

According to Osborn, the past evolution of mammalian faunas is characterised by the existence of seven faunal phases spanning the Cainozoic. These phases are defined according to three different criteria: (1) the degree of continental separation and reunion of mammalian faunas in North America (Nearctica) and Europe (Palaearctica), (2) the struggle and competition between archaic primitive mammals (descended from Mesozoic ancestors) and more modern mammals, mostly ancestors of existing families and (3) the independent evolution of families in North America and Europe during periods of separation without interchange by migration.

Osborn's review of the known mammalian fossil record from the Asiatic region made its limitations very clear, as the oldest known fauna in 1910 was Miocene in age.

> The wonderful mammalian fauna of Asia still awaits stratigraphic arrangement; that is, the geologic or time succession of the mammals is still to be worked out. On this and on further exploration, especially of the smaller forms of life, depends the question of the origin and history of some of the most important Old World types.

The Miocene is documented in India in the Lower Manchhar and Bugti faunas (located in western India, the Manchhar on the flanks of the Kirthar Range and the Bugti on the southern portion of the Suleiman Range). This Middle Miocene fauna of western India had been described by Max Schlosser (1903) as the "*Anthracotherium* fauna" and Osborn highlights its predominantly browsing character, which explains the absence of *Hipparion* and other grazing forms typical of the period, and also the fact that "it contains some survivals of European browsing types of Oligocene and Lower Miocene age" (Osborn, *ibid.*, p. 276).

The Pliocene mammalian fauna of Asia was made up of a very rich, abundant and cosmopolitan assemblage containing contributions from Europe, Africa and North America as well as autochthonous southern Asiatic forms. Two regions were recognised: the southern Asiatic region represented by an assemblage from the Siwalik beds in the foothills of the Himalayas, and the eastern Asiatic region, characterised by scattered deposits in Burma, China and Japan. In both areas, the precise locality and horizon of the fossils collected was not precisely known, as most of the material was obtained by untrained collectors.

A survey of the southern Asiatic fauna based on the extensive studies of Falconer and Lydekker demonstrated that the region was a centre of evolution for anthropoid apes, catarrhine monkeys (Old World monkeys), hollow-horned ruminants and proboscideans (elephants).

The eastern Asiatic region was still poorly known, and most of Osborn's description was based on Schlosser's study of the fossil mammals known from China (Schlosser, 1903). Again, as in the case of most of the southern Asiatic material, stratigraphic information was relatively scarce, and the problem was all the more acute since most of the fossil remains were, in fact, gathered from drug stores where they were known as "dragon bones" and used in pharmaceutical preparations. However, records of their provenance were available: most seemed to be Late Miocene or Early Pliocene in age. These faunas contained abundant north Asiatic hipparions, hornless rhinoceroses (aceratheres), large browsing horses (anchitheres), mastodons and a wide variety of ruminants (Osborn, *op. cit.*, p. 333). Schlosser (1903) distinguished two types of fauna: an open plains fauna found in Shansi (northern China) and Sichuan (western China) provinces and a forest fauna, found in Hunan and Hubei provinces (central China).

William Diller Matthew and Climate and Evolution

One of Osborn's colleagues at the American Museum of Natural History, W.D. Matthew, a vertebrate palaeontologist with an extensive training and interest in the geological dimension of the fossil record, tackled the problem of the past and present distribution not only of fossil mammals, but of other fossil vertebrates, invertebrates and plants (Matthew, 1915, 1939). Whereas Osborn's review was structured stratigraphically, Matthew structured his taxonomically and devoted much space to the centres of origin and methods of dispersal. Matthew's thesis, inspired by Chamberlin's work (Chamberlin, 1897), was that dispersal was very much controlled by alternating periods of (1) continental connection characterised by zonal, cold and arid climates and the evolution of cosmopolitan faunas, and (2) continental isolation characterised by uniform, warm and moist climates, restriction of land migration and development of provincial faunas. According to Matthew (1939, p. 9), mammalian history demonstrated that:

> ...the present distribution of mammals is due chiefly to migration from the great northern land mass, and the connection of this southward march with progressive refrigeration in the polar regions was made more than a century ago (1778) by Buffon. With a clearer perspective of geological time and far more exact records, it is clear that most of this deployment and dispersal of the mammalian races has taken place since the Eocene Epoch of the Tertiary, although remnants of an older dispersal on the same lines are probably traceable in the present habitats of monotremes, marsupials and primitive insectivores.

Matthew strongly rejected the hypothesis of connection between the southern continents (South America, Africa, Australia and Antarctica) on the grounds that: (1) the evidence for the isostatic balance of continents and ocean basins was very strong; (2) the exceptional cases of faunal distribution where former equatorial and southern connections could be inferred, can often be accounted for in other ways such as imperfections in the geological record, parallel evolution and rare overseas transportation on rafts; (3) the presence of such land bridges would have affected other sections of the fauna which did not show such effect.

In his review of the distribution of the various mammalian groups, Matthew demonstrated that the central Asiatic region was an important centre of evolution and dispersal for man and other primates (anthropoid apes, monkeys, baboons and lemurs). He noted that among the Carnivora, the Ursidae seem to have evolved from three ancestral series found respectively in Europe, China and India. According to Matthew, the three modern families of Perissodactyla (tapirs, rhinoceroses and horses) seemed to have emerged somewhere in central Asia, which was also an important centre for the evolution and dispersal of many ruminant groups among Artiodactyla such as deers, antelopes, sheep and goats, musk oxen and the extinct anthracotheres.

Lastly, the fossil record of Proboscidea (elephants and mastodons) also indicated that Asia was a centre of dispersal for this group.

Two main conclusions of Matthew's work were that central Asia had been a major centre for mammalian evolution and that further exploration, especially of the pre-Pliocene fossil record, was needed to refine the conclusions drawn from an often incomplete and poorly documented record.

Matthew, Grabau and the continental drift hypothesis

In a "Note on the Wegener Hypothesis" found undated and in manuscript form among Matthew's papers after his death and published in a new edition of his essay (Matthew, 1939), Matthew highlighted the difficulty of reconciling the fossil record and the hypotheses put forward by the "bridge-builders". Fossil evidence was often adduced to support theories of continental drift in contradiction to what was known of the Tertiary mammalian fossil record. According to Matthew (1939, p. 169):

> I cannot see how to fit it into the Tertiary mountain-making movements without involving radical changes in the relations of the Tertiary continents which run wholly counter to the evidence of the Tertiary mammal record.
>
> ...
>
> But if there were no other difficulties, the mammalian faunas of Africa and South America, of North America and Europe, in their relations to Asia afford sufficient proof that these continents were in substantially the same relations at the beginning of the Tertiary as they are today.

Matthew was much more tolerant of the continental drift theory in a more or less modified form as a model for Palaeozoic and Mesozoic geological evolution. His position is representative of the early American reaction to Wegener's concept of continental drift. Wegener's ideas, as developed in his 1915 monograph "The Origin of Continents and Oceans" attracted much scepticism around the world, but while the European reactions were mixed, the American reaction was one of almost unanimous rejection as exemplified by the symposium held in New York in 1926 under the auspices of the American

Association of Petroleum Geologists (LeGrand, 1988). According to LeGrand, the grounds for rejection of the continental drift model included the non-scientific methodology of Wegener, the distortion needed to make the modern continents fit into a past supercontinent, the connection between drift and geological catastrophism and the nature of Wegener's palaeoclimatological, biogeographical and geodetic evidence. The virulence of that rejection may well have been fuelled by residual anti-German feelings resulting from World War 1. It is interesting to note in this context that Amadeus Grabau, an American palaeontologist and geologist of German descent was in the process of developing a theory of world-wide, synchronous marine transgressions and regressions based on detailed correlation between stratigraphic deposits of Asia with those of North America. His "pulsation theory" was developed during the American (1900-1919) and the Chinese (1920-1946) phases of his career and first presented in 1923 at the 16th International Geological Congress in Washington, D.C. (Marvin, 1991). Out of the main theories put forward at the beginning of the twentieth century to account for the distribution of continents and oceans (Dana's theory of permanence, Suess's contractionist hypothesis and Wegener's continental drift hypothesis), Grabau came to favour Wegener's ideas: the existence in the Palaeozoic of a single land mass, Pangaea, provided him with a better framework to explain the apparently global effects of sea level changes than scattered continents separated by deep oceans.

2.2 - VERTEBRATE PALAEONTOLOGY AT THE TURN OF THE TWENTIETH CENTURY: A BIO-BIBLIOGRAPHIC SURVEY

A representation of the topography of the palaeontological landscape at the turn of the 20th century can be obtained from a survey of the main contributors to this field of knowledge, their location and their mode of operation. Data were collected for all contributors who had more than 20 entries in Romer *et al.* (1962), including at least five entries later than 1880 and five entries earlier than 1920. 211 contributors fitted this selection criterion; they were distributed in at least 23 different countries. The main criterion for inclusion in the Romer *et al.* bibliography was "value". According to Romer *et al.* (*ibid.*):

> The problem of limits on inclusion has been of continual concern. It has sometimes been suggested to us that we include only papers of "substantial" value. But while the mere notion of the find of a shark tooth dug up in a marine formation or of a mammoth tooth dug up in the garden of a member of a local French learned society is not earth shaking, an item of this sort may be of real value to a worker on geographic or stratigraphic phases of the subject. Popular articles by recognized scientists often contain summaries or interesting expressions of opinion which are not contained in these authors' more learned (and pedestrian) works. Even popular articles by non-specialists have not infrequently appeared valuable enough to merit inclusion.

COUNTRY	NUMBER OF SCIENTISTS
Germany	43
France	36
England	28
United States *	16
Czechoslovakia	12
Hungary	8
Switzerland	11
Austria	10
Italy	10
Sweden	6
Belgium	5
Scotland	5
Spain	4
Argentina	3
Russia	3
Holland	2
Estonia	2
Australia	2
Canada	1
Denmark	1
Romania	1
South Africa	1
Yugoslavia	1

Table 2.1: Global Distribution of Vertebrate Palaeontologists at the turn of the 20th century

(from Romer *et al*, 1962; United States* under-represented in this survey because of inclusion criteria in Romer *et al.*, *ibid.*)

In addition, there were 57 individuals whose country of origin could not be ascertained. Romer *et al.* (*ibid.*) have only listed entries which contained non-American material. Hay (1902) had published a bibliography and catalogue of the fossil vertebrates in North America up to 1900, followed in 1929 by a second bibliography and catalogue (Hay, 1929) covering the next 27 years. Romer *et al.* (1962) have only reproduced those entries in Hay (1902 and 1929) that contained references to non-American material.

In order to cope with this plethora of contributors, it was decided to narrow this survey to 10% of the contributors, those at the top of the list. They are the following 26 scientists:

NAME	COUNTRY	NUMBER OF ENTRIES
OWEN, Richard	England	364
WOODWARD, Arthur Smith	England	347
LYDEKKER, Richard	England	323
GAUDRY, Albert	France	252
NEHRING, Alfred	Germany	230
BROOM, Robert	South Africa	187
COPE, Edward Drinker	U.S.	183
DOLLO, Louis	Belgium	178
DEPERET, Charles	France	156
AMEGHINO, Florentino	Argentina	155
ABEL, Othenio	Germany	153
SEELEY, Harry Govier	England	147
TRAQUAIR, Ramsay Heatley	Scotland	144
OSBORN, Henry Fairfield	U.S.	142
BOULE, Marcellin	France	134
FILHOL, Henri	France	131
SAUVAGE, Henri-Emile	France	122
JAEKEL, Otto	Germany	119
ANDREWS, Charles William	England	118
HUENE, Friedrich von	Germany	116

FRAAS, Eberhard	Germany	114
SCHAAFHAUSEN, Hermann	Germany	110
BARKAS, Thomas Pallister	England	102
CAPELLINI, Giovanni	Italy	97
RIVIERE De PRECOURT, Emile	France	93
LERICHE, Maurice	France	90

Table 2.2: Geographic Distribution of Leading Vertebrate Palaeontologists at the turn of the 20th century.

These represented 8 of the 23 countries in the full list. These countries are: France (8 scientists), Germany (6 scientists), England (6 scientists), United States (2 scientists), Argentina (1 scientist), Italy (1 scientist), Scotland (1 scientist), South Africa (1 scientist).

Table 2.3 summarises the salient features of the biography and scientific contribution of each of these 26 leading vertebrate palaeontologists. These data were collected in Sarjeant (1980), in Gillispie (1970) and the references therein. The spread of nationalities, of course, reflects the gradual spread of vertebrate palaeontology from continental Western Europe and England. Robert Broom (South Africa) and Florentino Ameghino (Argentina) stand out as the most far-flung of our contributors. A short biographic sketch of a selection of these contributors to palaeontology and palaeoanthropology highlights several characteristics of the modus operandi in these fields of research at the turn of the twentieth century.

Table 2.3 - Biogeographical sketch for leading vertebrate palaeontologists at the turn of the 20th century

NAME	DATE (PLACE) OF BIRTH - DATE (PLACE) OF DEATH	OCCUPATION	HIGHLIGHTS	CAREER
ABEL, Othenio	1875 (Germany)- 1946(Germany)	- Vertebrate & invertebrate Palaeontologist - Stratigrapher - Palaeoichnologist	- Geological work in U.S. & West Indies - Studies of folklore of fossils in Germany & Austria	- University of Vienna, Austria - Director, Palaeontological Institute, Gottingen, Germany
AMEGHINO, Florentino	1854 (?Argentina) - 1911 (Argentina)	- Vertebrate Palaeontologist - Stratigrapher	- First detailed description of South American Eocene to Miocene mammalian faunas (more than 500 new genera) - Miscorrelation of South American faunas with Mesozoic rocks elsewhere); Hypothesis that Argentina was a centre of radiation of mammals - Mistaken belief in the presence of Tertiary Man in South America	- University o. Cordoba (1881-1886) - Museum of La Plata (1886-1902) - Director of National Museum, Buenos Aires
ANDREWS, Charles William	1866 (England) - 1924 (England)	- Vertebrate Palaeontologist	- Quaternary flightless birds - Jurassic marine reptiles (Leeds Collection from England) - Tertiary mammals from Egypt & East Africa	- British Museum (Natural History)
BARKAS, Thomas Palliser	1819 (England) - 1891 (England)	- Stratigrapher - Vertebrate & Invertebrate Palaeontologist	- Geology of the Northumberland coal field	- Builder, then bookseller - Fellow of Royal Society, London

Table 2.3: Biographical sketch for leading vertebrate palaeontologists at the turn of the 20th century

NAME	DATE (PLACE) OF BIRTH-DATE (PLACE) OF DEATH	OCCUPATION	HIGHLIGHTS	CAREER
BOULE, Marcellin	1861 (France) - 1942 (France)	- Geologist - Palaeontologist	- 'Father' of French palaeoanthropology - Anatomical description of Neanderthal Man (from La-Chapelle-aux-Saints)	- Museum of Natural History, Paris. - Director, Institute of Human Palaeontology, Paris
BROOM, Robert	1866 (Scotland) - 1951 (?South Africa)	- Physician - Vertebrate Palaeontologist	- Human/pre-human palaeontology - Karroo mammal-like reptiles	- Transvaal Museum (1934-1951)
CAPPELLINI, Giovanni	1833 (Italy) - 1922 (Italy)	- Stratigrapher - Vertebrate and Invertebrate Palaeontologist - Prehistorian	- Geology of Austria & Rumania - Early Darwinist	- Professor of Geology at Bologna & Genova
COPE, Edward Drinker	1840 (U.S.) - 1897 (U.S.)	- Zoologist - Vertebrate Palaeontologist	- Living & fossil reptiles, amphibians, fishes & Tertiary mammals - Demonstrated the importance of dentition in classification of mammals and of hoof structure in classification of horses - Permian reptiles of Texas - Dinosaurs (competition with O.C. Marsh)	- Full-time collector
DEPERET, Charles	1854 (France) - 1929 (France)	- Vertebrate Palaeontologist - Stratigrapher - Structural Geologist	- Tertiary & Quaternary geology & stratigraphy of southern France - Tertiary mammals	- Faculty of Science, University of Lyons (from 1889)

Table 2.3: Biographical sketch for leading vertebrate palaeontologists at the turn of the 20th century (Continued)

NAME	DATE (PLACE) OF BIRTH-DATE (PLACE) OF DEATH	OCCUPATION	HIGHLIGHTS	CAREER
DOLLO, Louis	1857 (France) – 1931 (Belgium)	- Vertebrate Palaeontologist	- Fossil fishes, reptiles, birds and their palaeoecology - Work on Iguanodon remains from Bernissart, Belgium - Principle of irreversibility of evolution	- Conservator at Museum of Natural History, Brussels (1882-1909) - University of Brussels (from 1909)
FILHOL, Henri	1843 (France) - 1902 (France)	- Zoologist - Vertebrate Palaeontologist	- Studies of fossil mammals in Quercy Phosphorites (1877), St Gerand-le-Puy (1879), Ronzon (1880)	- Professor of Comparative Anatomy, Museum of Natural History, Paris
FRAAS, Eberhard	1862 (Germany) - 1915 (Germany)	- Stratigrapher - Vertebrate Palaeontologist	- Studies on Triassic reptiles (ichthyosaurs) and amphibians, Jurassic marine crocodiles & plesiosaurs of Germany, dinosaurs of East Africa (Tendaguru)	- Professor of Palaeontology at the University of Stuttgart - Head of the Royal Museum (Stuttgart)
GAUDRY, Albert	1827 (France) - 1908 (France)	- Palaeontologist	- 1855 & 1860, excavations in Tertiary mammal deposit of Pikermi (Attica) - Early work on starfishes - Studies of fossil mammals and fossil man - Biographical studies of geologists - Museum of evolution	- Professor of Palaeontology (Jardin des Plantes, Paris (1872-1903))

Table 2.3: Biographical sketch for leading vertebrate palaeontologists at the turn of the 20th century (Continued)

NAME	DATE (PLACE) OF BIRTH-DATE (PLACE) OF DEATH	OCCUPATION	HIGHLIGHTS	CAREER
HUENE, Friedrich von	1875 (Germany) - 1969 (Germany)	- Invertebrate & Vertebrate Palaeontologist	- Early Stratigraphic work in Switzerland & studies of Silurian brachiopods - Collection of mammals in Argentina (1823), Karroo reptiles in South Africa (1924) & dinosaurs in Brazil (1928) - Major collections and studies of German plateosaurs, placodonts, ichthyosaurs & other reptiles	- University of Tubingen
JAECKEL, Otto	1863 (Germany)-1929 (Germany)	- Invertebrate & Vertebrate Palaeontologist	- Fossil echinoderms, fish & reptiles	- University of Greifswald - University of Canton (China)
LERICHE, Maurice	1875 (?France) - 1948 (?Belgium)	- Invertebrate & Vertebrate Palaeontologist - Stratigrapher	- Tertiary fishes - Belgian stratigraphy (esp. Eocene)	- Professor of Geology, Université Libre, Brussels (1910-1948)
LYDDEKER, Richard	1849 (England) - 1915 (England)	- Vertebrate palaeontologist - Stratigrapher - Zoologist	- Geology of Kashmir - Fossil mammals of Siwalik Hills - Fossil Mesozoic reptiles - Catalogue of the entire vertebrate collection of British Museum (Natural History) - Author of Mammals Living and Extinct (with W. Flower, 1896) and The Geographical History of Mammals	- Geological Survey of India (1874-1882) - British Museum (Natural History) (from 1883)

Table 2.3: Biographical sketch for leading vertebrate palaeontologists at the turn of the 20th century (Continued)

NAME	DATE (PLACE) OF BIRTH-DATE (PLACE) OF DEATH	OCCUPATION	HIGHLIGHTS	CAREER
NEHRING, Alfred	1845 (Germany) - 1904 (Germany)	- School Teacher - Prehistorian - Vertebrate Palaeontologist	- Faunas from German cave deposits	- Professor of Zoology at Landwirtschaftlichen Hochschule (Berlin) from 1881
OSBORN, Henry Fairfield	1857 (U.S.) - 1935 (U.S.)	- Vertebrate Palaeontologist - Zoologist - Comparative Anatomist - Prehistorian - Historian of Geology	- Evolutionary studies - Field expeditions - Vertebrate evolution (esp. reptiles & mammals) - Public education & museum presentation of fossils (with C. Knight)	- Princeton University (1881-1890) - Columbia University, New York and American Museum of Natural History (from 1891)
OWEN, Richard	1804 (England) - 1892 (England)	- Comparative Anatomist - Zoologist - Vertebrate Palaeontologist	- Dissection of animals from Zoological Gardens and comparison with fossil forms - Coined term "dinosaur" and described first sauropod dinosaur *Cetiosaurus* - First description of *Archaeopteryx* and New Zealand moas - Staunch opponent of Darwinism	- first Hunterian Professor of Comparative Anatomy & Physiology and Conservator of the Hunterian Museum, Royal College of Surgeons (1836-1856) - Superintendent of Natural History Dept at British Museum (1856-1871) - First Director of British Museum (Natural History) (1871-1884)
RIVIERE DE PRECOURT, Emile	1835 (France) – 1922 (France)	- Palaeoanthropologist - Archaeologist	- Cromagnon remains in Grimaldi Caves (Italy)	- Medical doctor

Table 2.3: Biographical sketch for leading vertebrate palaeontologists at the turn of the 20th century (Continued)

NAME	DATE (PLACE) OF BIRTH-DATE (PLACE) OF DEATH	OCCUPATION	HIGHLIGHTS	CAREER
SAUVAGE, Henri-Emile	1842 (France)-1917 (France)	- Ichthyologist -Vertebrate palaeontologist - Stratigrapher	- Carboniferous to Tertiary fishes from France, Sicily, Algeria & Spain	- Assistant, Museum of Natural History, Paris - Conservator, Municipal Museum & Station Aquicole, Boulogne-sur-Mer, France
SCHAAFHAUSEN, Hermann	1816 (Germany)-1893 (Germany)	- Physician - Anthropologist - Vertebrate palaeontologist	- Quaternary mammals & fossil man	N/A
SEELEY, Harry Govier	1839 (England)-1909 (England)	-Vertebrate palaeontologist - Stratigrapher	- Major studies in the Karroo of South Africa - Work on anapsid and synapsid reptiles, pterodactyls & dinosaurs	- Woodwardian Museum, Cambridge (1860-1870) - British Museum (Natural History) (1870-1890) - Royal Indian Engineering College, London (1890-1896) - King's College, London (from 1896)
TRAQUAIR, Ramsay Heatley	1840 (Scotland)-1912 (Scotland)	- Palaeontologist - Museologist	- Palaeozoic fishes of Old Red Sandstone	- Royal Scottish Museum, Edinburgh
WOODWARD, Arthur Smith	1864 (England)-1944 (England)	-Vertebrate palaeontologist - Museologist	- Studies of fossil fishes (Late Jurassic/Cretaceous) - Author of Catalogue of British Vertebrata (with C.D. Sherbon, 1890) and of Outlines of Vertebrate Palaeontology (1898)	- British Museum (Natural History (1882-1924)

Table 2.3: Biographical sketch for leading vertebrate palaeontologists at the turn of the 20th century (Continued)

Robert Broom was born in Scotland where he trained as a surgeon and became interested in palaeontology before emigrating to South Africa. As well as following a successful medical career there, he was one of the first palaeontologists to describe the mammal-like reptiles of the Karroo Basin. He became a collaborator of Raymond Dart, finding the remains of the robust form of the australopithecine hominid the latter had recognised, thus starting the process that would see Africa replace Asia as the cradle of humankind.

Florentino Ameghino, often described as the founder of Argentinian palaeontology, was trained mostly locally, except for a three-year trip to Europe (1878 - 1881), during which time he presented a paper at the French Exposition in 1878 on fossil man in the Argentinian pampas, visited museums and took courses at the Museum of Natural History in Paris and the School of Anthropology. He then went on to become the Director of the National Museum in Buenos Aires. His main claims to fame remain his work on fossil mammals based on material collected by his brothers Carlos and Juan as well as his controversial theory regarding Argentina as the centre of radiation for mammals and his mistaken belief that man was present in the Tertiary formations of South America.

These views were contradicted by another scientist of the time, **Richard Lydekker**, an Englishman, who in 1893, accepted an invitation from the La Plata Museum to examine the material collected by Ameghino and concluded that it was considerably younger than Ameghino had claimed. This took part in the latter part of Lydekker's career, when he became associated with the British Museum (Natural History). Before that, he had been appointed to the Geological Survey of India (between 1874 and 1881), during which time he made extensive studies of the geology of Kashmir, the fossil mammals of the Siwalik Hills. The results of these studies, published in Paleontologica Indica, were to form the basis for Osborn's understanding of the mammalian fauna in Western India.

Before turning to the dominant figure of 19th century vertebrate palaeontology, Richard Owen, and his American counterpart during the first half of the 20th century, Henry Fairfield Osborn, it would be useful to note some characteristics arising from these first three examples:

- the far-flung location of their field work which contributed to the increasingly global documentation of the fossil record
- the colonial element in Lydekker's career, Broome's almost "amateur' beginnings and the almost autodidactic training of Ameghino spurred on by the geological appeal of his native province
- the close association with a museum and collections for reference
- the role of family connections in Ameghino's case and the close association with collectors/prospectors.

Richard Owen is the scientist at the top of Table 2.2 (*i.e.* the most prolific author) and, certainly, the towering figure in comparative anatomy, zoology and vertebrate palaeontology during the 19th century. He was also the first Director of the Natural History section of the British Museum when it gained its independence from the other collections. It is during this later part of his career that he became increasingly concerned with palaeontology, because of the rich collections he had at his disposal. He had, however, made important contributions during his time at the Museum of the Royal College of Surgeons, such as the description of the New Zealand moa (*Dinornis*) and of the Jurassic bird *Archaeopteryx*. His position at the British Museum (Natural History) made him the favoured recipient for fossils collected abroad, and he described much of the fossil material from Australia and New Zealand as exploration and settlement took place. He also described some mammal teeth from China, which had been collected by travellers without information about their location and age.

Owen's later counterpart on the other side of the Atlantic was **Henry Fairfield Osborn**. Like Owen, he had reached the top of the hierarchy of a major museum, the American Museum of Natural History, of which he was the President for many years as well as the Head of the Department of Vertebrate Palaeontology (which he founded). He was also associated with Columbia University where he trained many students. He came from a well-connected family and, as a result, was able to raise funds which financed the purchase of many collections (including that of Edward Drinker Cope, another major contributor in the list) and the launching of expeditions to the American West and Central Asia in the 1920's. He was keenly interested in public education and the dramatic presentation of extinct animals in museum displays. He showed an exceptional combination of public skills and scientific productivity (he was concerned with the details of vertebrate evolution, especially mammalian evolution, but was also a great synthesist, concerned about the origin and radiation of mammals).

In both Owen and Osborn, we see illustrated the importance of museums, as central repositories for collections, both for reference and public education, and foci of networks of correspondents. Osborn's family connections gave him access to the wealthy establishment of New York and to funds which allowed him to develop the collections, both through the purchase of private collections and the launching of major expeditions that resulted in the documentation of the fossil record in remote locations.

Two of the French contributors on this list present some interesting features. **Marcellin Boule** is of special interest to the elucidation of the fossil record of China and Central Asia: he was a geologist and a palaeontologist based at the Museum of Natural History in Paris, where he was the Director of the Institute of Human Palaeontology. There, he taught Teilhard de Chardin, whose expertise he recommended to Emile Licent, a Jesuit in Tianjin, China. Licent, in the course of expeditions designed to build the collections of his new museum, was turning up more and more vertebrate fossil remains. Teilhard eventually became a major contributor to the growing knowledge of the Chinese and Central Asiatic fossil vertebrate record. Boule, of course, is better known for his pioneering work in palaeoanthropology, where his approach was grounded in stratigraphic geology, palaeontology and archaeology.

Boule started his career as a junior collaborator of **Albert Gaudry**, who was also based at the Paris Museum. Gaudry participated in a geological mission to the Eastern Mediterranean region, sponsored by the French Academy of Sciences, in the course of which he collected the material that enabled him to draw one of the earliest phylogenetic trees of mammals. Later, he became the assistant to Alcide d'Orbigny, the founder of stratigraphic palaeontology and the foundation Professor of Palaeontology at the Paris Museum and, also, his brother-in-law. Gaudry was interested in the fossil record of man and evolutionary studies (he was a supporter of evolution by continuous divine creation) as well as public education about evolution.

CONCLUSION

The bio-bibliographic sketch presented above has illustrated several points about the dynamics of vertebrate palaeontology at the turn of the century

1. the importance of networks: familial, public and scientific.
2. the rising role of museums
   - as repositories of collections both for reference and public education
   - as central foci for networks of correspondents such as collectors, travellers and scientists in remote locations.
3. the interaction between museums and governments (occasionally through the colonial arm of these governments), between museums and the financial establishment in order to raise funds to finance expeditions
4. the function of exploration in vertebrate palaeontology (a field science par excellence) and of new collection techniques as new technologies became available.

These factors were critical in the discovery of new fossil fields such as the Karroo Basin, the American West and Central Asia. These in turn provided some of the answers to the increasingly global questions regarding the origin and radiation of major vertebrate groups as well as to questions about the evolutionary relationship between groups.

As a result of these developments, the Central Asiatic fossil vertebrate record acquired greater significance, primarily because of its relevance to mammalian evolution and the question of the origin and dispersal of important vertebrate groups. At the beginning of the 20th century, the hypothesis that Central Asia was the cradle of mammalian evolution was proposed by Osborn (1910) and Matthew (1915). A multinational effort set out to prove or disprove this hypothesis and, in the process, achieved much more.

REFERENCES

BONAPARTE, J.F., 1969. Dos nuevas "faunas" de reptiles Triásicos de Argentina. *Gondwana Symposium, Mar del Plata Ciencias Tierra* 2, pp. 282 – 306.

BOUCHER DE PERTHES, J., 1847. *Antiquités Celtiques et Antédiluviennes. Mémoire sur l'industrie primitive et les arts à leur origine.* Paris, 2 Vols.

BREITHAUPT, B.H., 1997. First golden period in the USA. *In* CURRIE, P.J. (Ed.), *Encyclopedia of Dinosaurs.* Academic Press, pp. 347-350.

BROWNE, J., 1983. *The Secular Ark - Studies in the History of Biogeography.* Yale University Press.

BUCKLAND, W., 1824. Notice on the *Megalosaurus*, or Great Fossil Lizard of Stonesfield. *Transactions of the Geological Society of London* 1 (Ser. 2), pp. 390 –396.

BUFFETAUT, E., CUNY, G. & LE LOEUFF, J., 1995. The discovery of French dinosaurs. *In* SARJEANT, W.A.S. (Ed.), *Vertebrate Fossils and the Evolution of Scientific Concepts - A Tribute to L. Beverley Halstead.* Gordon and Breach Publishers, pp. 159-180.

CARROLL, R.L., 1988. *Vertebrate Palaeontology and Evolution.* W.H. Freeman & Co, New York.

CHAMBERLIN, T.C., 1897. A group of hypotheses bearing on climatic changes. *Journal of Geology* 5, pp.653 – 683.

CHAMBERLIN, T.C. & SALISBURY, R.D., 1905 – 1907. *Geology.* Holt, New York, 3 vols.

CUVIER, G., 1796. Mémoire sur les espèces d'éléphants vivants et fossiles. *Magasin Encyclopédique,* 2ème année 3, pp. 440-445.

CUVIER, G., 1801. Extrait d'un ouvrage sur les espèces de quadrupèdes dont on a trouvé les ossements dans l'intérieur de la terre. *Journal de Physique, de Chimie et d'Histoire Naturelle* 52, pp. 253-267.

CUVIER, G. & BRONGNIART, A. (1808). Essai sur la géographie minéralogique des environs de Paris. *Journal des Mines* 23, pp. 421 –458.

DART, R.A., 1925. *Australopithecus africanus*: The Man-Ape of South Africa. *Nature* 115 (2884), pp. 195-199.

DARWIN, C., 1859. *On the Origin of Species by Means of Natural Selection.* Murray, London.

DE LAUNAY, 1913.*La Science Géologique: Ses Méthodes, ses Résultats, ses Problèmes, ses Problèmes, son Histoire.* Colin, Paris.

DUBOIS, E., 1892. Palaeontologische onderzoekingen op Java. *Verslag van het Mijnwezen* 3, pp. 12 – 14.

DUBOIS, E., 1894. *Pithecantropus erectus, eine menschenähnliche Uebergangsform aus Java.* Batavia.

EVANS, A.H., 1899. Birds. *In* HARMER, S.F. & SHIPLEY, A.E., Eds. *The Cambridge Natural History,* Vol. IX, Macmillan & Co Ltd, England

FÜRBRINGER, M., 1888. *Untersuchungen zur Morphologie und Systematik der Vögel.* Amsterdam.

GAUDANT, J., 1980. Louis Agassiz (1807-1873), fondateur de la paléoichthyologie. *Revue d'Histoire des Sciences* 33, pp 151-162.

GAUDRY, A., 1862 –1867. *Animaux Fossiles et Géologie de l'Attique d'après les Recherches faites en 1855 – 56 et 1860 sous les auspices de l'Académie des Sciences.* Paris.

GILLISPIE, C.C., Ed., 1970. *Dictionary of Scientific Biography.* Scribner, New York.

GOODRICH, E. S., 1916. On the classification of the Reptilia. *Proceedings of the Royal Society of London* LXXXIX, pp. 261-276.

GREENE, M., 1985. Plate tectonics and biogeography in historical perspective. *Earth Sciences History* 4, pp. 93-97.

GREGORY, W.K., 1915. Present status of the problem of the origin of the Tetrapoda with special reference to the skull and paired limbs. *Annals of the New York Academy of Sciences* XXVI, pp 317-383.

HAECKEL, E., 1868. *Natürliche Schöpfungsgeschichte.* Berlin.

HALSTEAD, L.B. & SARJEANT, W.A.S., 1995. *Scrotum humanum* Brookes - The early name for a dinosaur. *In* SARJEANT, W.A.S., Ed., *Vertebrate Fossils and the Evolution of Scientific Concepts - A Tribute to L. Beverley Halstead.* Gordon and Breach Publishers, pp. 219-222.

HAY, O.P., 1902. *Bibliography and Catalogue of Fossil Vertebrata of North America.* Bulletin of the U.S. Geological Survey No 179.

HAY, O.P., 1929. *Second Bibliography and Catalogue of the Fossil Vertebrata of North America.* Carnegie Institute, Washington, Publication 390.

HUXLEY, T.H., 1868. On the animals which are most nearly intermediate between birds and reptiles. *Annals and Magazine of Natural History* (Ser. 4) 2, pp. 66 – 75.

JANVIER, P., 1996. *Early Vertebrates.* Clarendon Press, Oxford.

KEITH, A., SMITH G.E., WOODWARD, A.S. & DUCKWORTH, W.L.H., 1925. The fossil anthropoid ape from Taungs. *Nature* 115 (2885), pp. 234-236.

KING, W., 1864. The reputed fossil man of the Neanderthal. *Quarterly Journal of Science* 1, pp. 88 – 97.

KOENIGSWALD, G.H.R., von & WEIDENREICH, F., 1939. The relationship between *Pithecanthropus* and *Sinanthropus. Nature* 144, 926-929.

LAMARCK, J.B., 1809. *Philosophie Zoologique.* Paris. *Philosophie zoologique, ou Exposition des considérations relatives à l'histoire naturelle des animaux ; à la diversité de leur organisation et des facultés qu'ils on obtiennent ; aux causes physiques qui maintiennent en eux la vie et donnent lieu aux mouvemens qu'ils exécutent ; enfin, à celles qui produisent les unes le sentiment et les autres l'intelligence de ceux qui en sont doués,* Dentu, Paris, 2 volumes.

LAMARCK, J.B., 1815-1822 . *Histoire naturelle des animaux sans vertèbres, présentant les caractères généraux et particuliers de ces animaux, leur distribution, leurs classes, leurs familles, leurs genres, et la citation des principales espèces qui s'y rapportent ; précédée d'une introduction offrant la détermination des caractères essentiels de l'animal, sa distinction du végétal et des autres corps naturels ; enfin, l'exposition des principes fondamentaux de la zoologie,* Déterville, Paris, 7 volumes.

LAUDAN, L., 1984. *Science and Values.* University of California Press.

LEGRAND, H.E., 1988. *Drifting Continents and Shifting Theories.* Cambridge University Press.

LEHMAN, J.P., 1955. Amphibiens, généralites. *In* PIVETEAU, J.(Ed.), *Traité de Paléontologie.* Masson & Cie, Paris, Vol. V, pp. 3-52.

LEIDY, J., 1858. *Hadrosaurus foulkii,* a new saurian from the Cretaceous of New Jersey. *Proceedings of the Academy of Natural Sciences of Philadelphia* 10, pp. 215-218.

LUBBOCK, J., 1865. *Prehistoric Times: As illustrated by Ancient Remains and the Manners and Customs of Modern Savages.* London.

LYDEKKER, R., 1885-1887. *Catalogue of the Fossil Mammalia in the British Museum (Natural History).* London.

LYDEKKER, R., 1896. *A Geographical History of the Mammals.* Cambridge.

MACLEOD, R.M., 1965. Evolutionism and Richard Owen, 1830-1868: An episode in Darwin's century. *Isis* 56(3), pp. 259-280.

MANTELL, G., 1825. Notice on the *Iguanodon,* a newly discovered fossil reptile, from the sandstone of Tilgate Forest, in Sussex. *Philosophical Transactions of the Royal Society of London* 115, pp. 179-186.

MARSH, O.C., 1896. The dinosaurs of North America. *U.S. Geological Survey 16th Annual Report 1894 –1895*, pp. 133 – 244.

MARVIN, U.B., 1991. Amadeus William Grabau's global theories in the light of current models. In WANG *et al.* (Eds), *Interchange of Geoscience Ideas Between the East and the West,* Proceedings of the XVth International Symposium of INHIGEO, China University of Geosciences Press, pp. 55-71.

MATTHEW, W.D., 1915. Climate and evolution. *Annals of the New York Academy of Sciences XXIV*, 171-318.

MATTHEW, W.D., 1939. *Climate and Evolution.* Second edition, revised and enlarged. Arranged by E.H. Colbert. Special Publications of the New York Academy of Sciences 1, 223 p.

MILNE-EDWARDS, A., 1868 - 1872. *Recherches anatomiques et paléontologiques pour servir à l'histoire des oiseaux fossiles de la France.* Paris, 3 Vols.

MOLNAR, R.E., 1982. A catalogue of fossil amphibians and reptiles in Queensland. *Memoirs of the Queensland Museum* 20, pp. 613 –633.

NORMAN, D., 1985. *The Illustrated Encyclopedia of Dinosaurs.* Crescent Books, New York.

OAKLEY, K.P. & HOSKINS, C.R., 1950. New evidence on the antiquity of Piltdown man. *Nature* 165, pp. 376-382.

OSBORN, H.F., 1910. *The Age of Mammals in Europe, Asia and North America.* The Macmillan Company, New York.

OWEN, R., 1841. A description of a portion of the skeleton of the *Cetiosaurus*, a gigantic extinct saurian occurring in the oolitic formations of different parts of England. *Proceedings of the Geological Society of London* 3, pp. 457 – 462.

OWEN, R., 1842a. On the teeth of a species of the genus *Labyrinthodon* (Mastodonsaurus of Jaeger), common to the German Keuper formation and the lower sandstone of Warwick and Leamington. *Transactions of the Geological Society of London* VI (2), pp. 503-513.

OWEN, R., 1842b. Description of parts of the skeleton and teeth of five species of the genus *Labyrinthodon* ... with remarks on the probable identity of *Cheirotherium* with this genus of extinct batrachians. *Transactions of the Geological Society of London* VI (2), pp. 515-543.

OWEN, R., 1842c. Report on British fossil reptiles. *Report to BAAS Plymouth 1841*, pp. 60 – 204.

OWEN, R., 1863. On the *Archaeopteryx* of von Meyer, with a description of the fossil remains of a long-tailed species from the lithographic stone of Solenhofen. *Philosophical Transactions of the Royal Society of London.* 153, pp. 33 – 47.

OWEN, R., 1866. *On the anatomy of vertebrates. I. Fishes and reptiles.* London.

PADIAN, K., 1997. The rehabilitation of Richard Owen. *Bioscience* 47(7), pp. 446-453.

PIVETEAU, J. 1955. Reptiles, généralités. *In* PIVETEAU, J. (Ed.), *Traité de Paléontologie.* Masson & Cie, Paris, Vol. V, pp. 324-330.

PRESTWICH, J., 1859. Sur la découverte d'instruments en silex associés à des restes de mammifères d'espèces perdues dans des couches non remaniées d'une formation géologique récente. *Compte-Rendus de l'Académie des Sciences (Paris)* 49, pp. 634 – 636.

PRESTWICH, J., 1860. On the occurrence of flint-implements, associated with the remains of extinct mammalia, in undisturbed beds of a late geological period. *Proceedings of the Royal Society of London* 10, pp. 50 – 59.

PRESTWICH, J., 1861. On the occurrence of flint-implements, associated with the remains of animals of extinct species in beds of a late geological period, in

France at Amiens and Abbeville, and in England at Hoxne. Philosophical Transactions of the Royal Society of London CL, pp. 277 - 317.

READER, J., 1981. *Missing Links - The Hunt for Earliest Man.* Collins, London.

RICH, T.H.V. & RICH, P.V., 1989. Polar dinosaurs and biotas of the Early Cretaceous of southeastern Australia. *National Geographic Research* 5, pp. 15 – 53.

ROMER, A.S., WRIGHT, N.E., EDINGER, T. & VAN FRANK, R. (1962). Bibliography of fossil vertebrates exclusive of North America, 1509-1927. *Geological Society of America Memoir* 87.

RUDWICK, M.J.S., 1976. *The Meaning of Fossils - Episodes in the History of Palaeontology.* The University of Chicago Press, Chicago and London, 2nd ed.

SARJEANT, W.A.S., 1980. *Geologists and the History of Geology - An International Bibliography from the Origins to 1978.* Macmillan Press, London.

SARJEANT, W.A.S., 1997. Early Discoveries. *In* CURRIE, P.J., (Ed.), *Encyclopedia of Dinosaurs.* Academic Press, pp. 340-346.

SCHLOSSER, M., 1903. Die fossilen Saugethiere Chinas nebst einer Odontographie der recenten Antilopen. *Abhandlungen bayer Akademie der Wissenschaften 22*, 1-221.

SCLATER, P.L., 1858. On the general distribution of the members of the Class Aves. *Journal of the Linnean Society (Zoology)* 2, pp. 130 – 145.

SMITH, W., 1816 –1819. *Strata Identified by Organized Fossils, Containing Prints on Colored Paper of the most Characteristic Specimens in Each Stratum.* London.

SPENCER, F., 1990. *Piltdown - A Scientific Forgery.* Natural History Museum Publications, Oxford University Press.

SUESS, E., 1904 – 1909. *The Face of the Earth.* Clarendon Press, Oxford, 4 vols.

TATTERSALL, I., 1995. *The fossil Trail - How We Know What We Think We Know About Human Evolution.* Oxford University Press.

THULBORN, R.A., 1970. The skull of *Fabrosaurus australis,* A Triassic ornithischian dinosaur. *Paleontology* 13, pp. 414 – 432.

WALLACE, A.R., 1855. On the law which has regulated the introduction of new species. *Annals and Magazine of Natural History* 16(2), 184-196.

WEISHAMPEL, D.B., DODSON, P. & OSMOLKSKA, H., 1990. *The Dinosauria.* University of California Press.

ZITTEL, K. von, 1901. *History of Geology and Palaeontology.* 1962 Reprint by J. Cramer. Weinheim. Wheldon and Wesley Ltd and Hafner Publishing Co., New York.

CHAPTER 3

THE FOSSIL VERTEBRATE RECORD OF CENTRAL ASIA AND CHINA: DISCOVERY AND EXPLORATION IN THE FIRST HALF OF THE TWENTIETH CENTURY

3.1 - PIERRE TEILHARD DE CHARDIN AND THE CHINESE VERTEBRATE FOSSIL RECORD

Pierre Teilhard de Chardin (Fig. 3.1) arrived in Tianjin (= Tientsin, China, see Fig. 3.2) on 23 May 1923, the result of an invitation by fellow Jesuit, Père Emile Licent. Licent had been in China since 1914 where he was based at the Jesuit College in Tianjin. After his arrival in China, he started exploring the Yellow River basin in order to collect geological, zoological and botanical specimens for the Hoangho Paiho Museum he had founded. In the course of these explorations, he had collected mammalian fossils, which he sent to Professor Marcellin Boule at the Paris Museum of Natural History for identification. The Paris Museum financed a French Palaeontological Mission to central China (1923), which Licent headed and where Teilhard de Chardin served as vertebrate palaeontologist.

Teilhard de Chardin had previously worked on mammalian fossils from the Early Cainozoic (see Box 3.1): he studied the Quercy phosphorites (Eocene to Oligocene) and Paleocene mammals from France and Belgium. In China, he moved up-section into the Late Tertiary and Quaternary. Teilhard de Chardin was also a geologist, and he became interested in the sedimentological, tectonic and igneous history of China as well as its fossils. Teilhard de Chardin spent most of the following 23 years in China, in the course of which he produced more than 150 papers on Chinese geology and palaeontology, published in a variety of scientific and general journals. The following account of Teilhard de Chardin's role in the discovery of the Chinese vertebrate record was made possible by Cuenot's extensive and exhaustive biography of Teilhard de Chardin (Cuenot, 1958) and by Schmitz-Moormann's compilation of all of Teilhard de Chardin's scientific papers (Schmitz-Moormann, 1971).

1891	Birth of Marie-Joseph Pierre Teilhard de Chardin
1899	Enters the Compagnie de Jésus (Order of Jesuits)
1915-1918	Takes part in the First World War as a stretcher-bearer
1919-1920	Studies at the Sorbonne in natural sciences
1920-1922	Studies for a doctorate on the Lower Eocene mammals in France under M. Boule
1923-1924	*First Tianjin period*: Field trips to the Ordos, Hebei Province and Inner Mongolia
1926-1927	*Second Tianjin period*: Field trips to central China, Sanggan He Valley and eastern Mongolia
1929	Becomes an adviser to the Geological Survey of China
1929-1930	*First Peking period:* Starts work on the Zhoukoudian Peking Man site. Field trips to Shanxi and Manchuria
1930	Takes part in the Central American Expedition
1931-1932	Takes part in the Haardt-Citroen Croisière Jaune (Yellow Expedition)
1932-1936	*Second Peking period*: Various field trips in China: to Shanxi, Henan and Shandong. Exploration of southern China (Guangdong and Guangxi) in order to establish correlations with the Zhoukoudian site)
1937	Travels to the U.S., returns to China
1937-1938	Takes part in the Harvard-Carnegie Expedition to Burma
1938	Short stay in Java, returns to China
1938-1939	Travels to the U.S. and France, returns to China
1939-1946	*Third Peking period*:
1940	Establishes the Peking Institute of Geobiology with Pierre Leroy
1943	Launches the journal Geobiologia
1946	Return to France
1946-1951	The Paris period during which he re-establishes contact with French science and becomes a member of the Academy of Science
1951-1955	The New York period during which he travels to Montana and the University of Berkeley. Association with the Wenner-Gren Foundation for Anthropological Research: travels to South Africa and Rhodesia.
1955	Sudden death in New York. Posthumous publication of The Phenomenon of Man.

Box 3.1 – Teilhard de Chardin: A biographical sketch

Fig. 3.1 – Teilhard de Chardin in 1920 (after Cuenot, 1963)

Fig. 3.4 – Teilhard de Chardin in 1939 (after Cuenot, 1963)

3.1.1 - The First Tianjin Period (1923-1924)

The collaboration with Licent had started before Teilhard de Chardin even set foot in China. In 1922, Teilhard de Chardin described a Pontian mammalian fauna collected by Licent in northeast Gansu (Teilhard de Chardin, 1922). In 1923, Licent and Teilhard de Chardin travelled to the Ordos Plateau in Inner Mongolia (Fig. 3.2), where Licent had previously recognised localities containing Late Cainozoic mammals and evidence of Palaeolithic stone tools. A series of papers resulted from this expedition, describing:

- the geology of the region: the relationship between the Ordos Platform and the folded surrounding chains to the north and west; the occurrence of Pliocene clay beds overlain by Lower Pleistocene gravel beds and a Recent True Loess phase. (Teilhard de Chardin & Licent, 1924)
- the occurrence of a Palaeolithic (Mousterian) industry, the first evidence ever recorded in central Asia. In their review of the Palaeolithic in China, Licent and Teilhard de Chardin (1925) described the Quaternary stratigraphy of northern China and Mongolia characterised by a succession of:

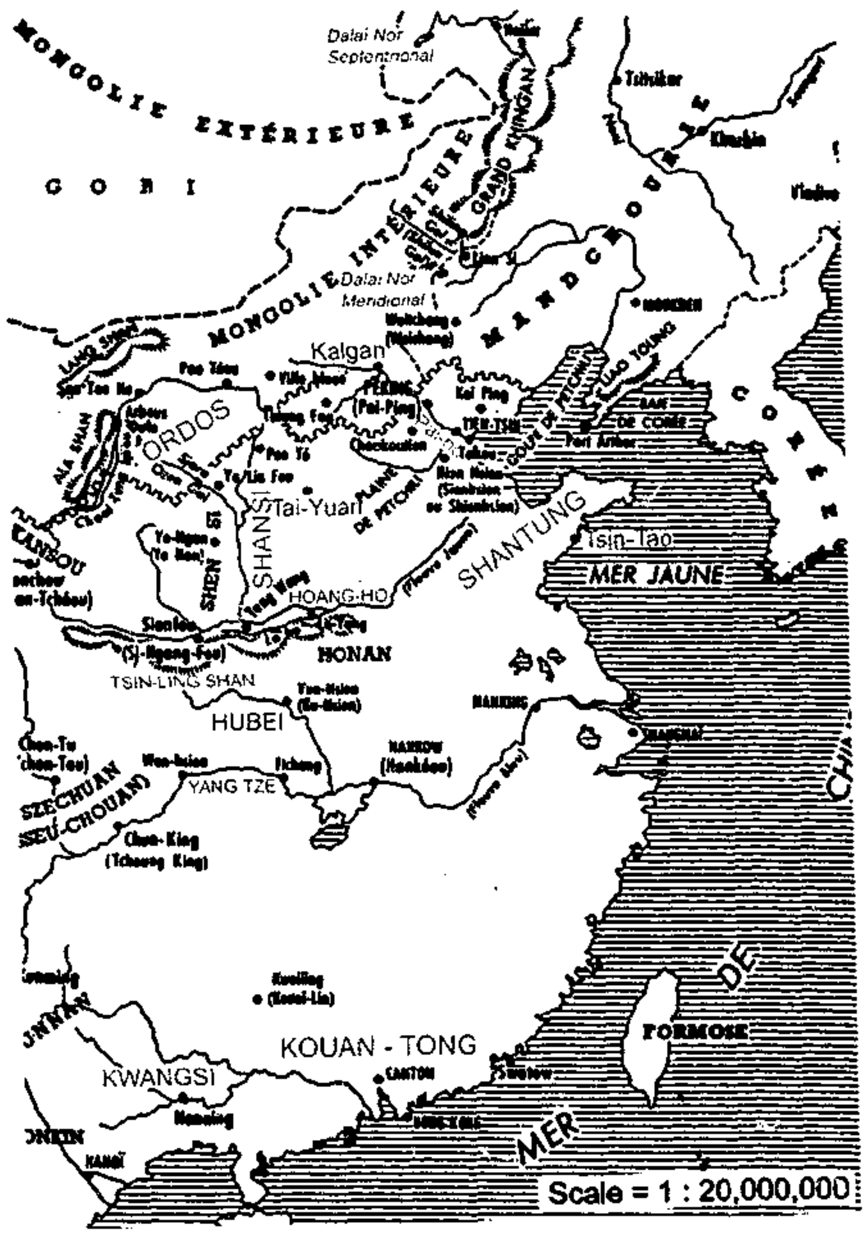
- lower Pleistocene *Quadrula* sands and red earths overlain by
- yellow earths hosting *Rhinoceros*, *Bos*, *Elephas* and *Struthiolithus* overlain by
- black Neolithic deposits.

The Palaeolithic industry was found to be restricted to the yellow earth deposits and was identified in 3 distinct sites.

In 1924, Teilhard de Chardin and Licent travelled to northern Hebei Province and the eastern part of Inner Mongolia in order to map the eastward extension of some fossil-bearing strata which had been recognised originally west of Kalgan by the Third Central Asiatic Expedition of the American Museum of Natural History in 1922. As a result of this expedition, the Quaternary Dalai Nur volcanic centre was described (Teilhard de Chardin, 1925) as well as fossil plants contained in the local Mesozoic sandstones (Teilhard de Chardin & Frittel, 1925).

Following these expeditions, Teilhard de Chardin published a major review of the Tertiary mammals of China and Mongolia (Teilhard de Chardin,

Fig. 3.2 – Map showing Chinese localities investigated by Teilhard de Chardin (after Cuénot, 1958)



MONGOLIE EXTÉRIEURE
GOBI
MONGOLIE INTÉRIEURE
GRAND KHINGAN
MANDCHOURIE
Dalai Nor Septentrional
Dalai Nor Meridional
Kalgan
ORDOS
Tai-Yuan
SHANSI
SHEN SI
SHANTUNG
Tsin-Tao
MER JAUNE
HOANG-HO
HONAN
TSIN-LING SHAN
HUBEI
YANG TZE
SZECHUAN
SEU-CHOUAN
KOUAN - TONG
KWANGSI
FORMOSE
MER DE CHINE
Scale = 1 : 20,000,000

1926a). The Sandaohu (St Jacques) fauna, characterised by the presence of *Baluchitherium* associated with other perissodactyls, rodents and ruminants, was found to be very similar to the Hsanda Gol fauna recognised 500 km to the north by the Central Asiatic Expedition and it was suggested by Teilhard de Chardin that the two faunas might be contemporaneous.

3.1.2 - The Second Tianjin Period (1926-1928)

After a stay in France, Teilhard de Chardin returned to China where he took part in three major field expeditions: to central China, the Sanggan He Valley (in Hebei Province, 130 km NW of Peking) and eastern Mongolia.

In 1926, Teilhard de Chardin, Licent and Davidson Black (Professor of Neurology and Anatomy at the Peking Union Medical College, see Box 3.2), announced the discovery of a human incisor found associated with Pleistocene faunal remains in the south-eastern Ordos deposits, and about 500 metres away from a locality containing Palaeolithic implements and kitchen remains (Licent, Teilhard de Chardin & Black, 1926). This "Ordos tooth" was the first actual skeletal element from Palaeolithic man ever discovered in Asia. Teilhard de Chardin also became interested in the Neolithic of China and reviewed the discoveries of human bones and artifacts made in several Chinese localities by J.G. Andersson (see Box 3.3) (Teilhard de Chardin, 1926b). These discoveries highlighted the existence of a proto-Chinese autochthonous civilisation around 3,000 years B.C. as well as the absence of any record between the Lower Ordos Palaeolithic and the more modern Neolithic characterised by an elaborate pottery style.

The central China expedition was originally planned to reach Lanzhou (Gansu province) and the eastern border of Tibet, but, because of civil war, was restricted to south-western Shanxi (Shansi) and northern Hunan (Honan). It led to the recognition of an intermediate series between the Lower Pliocene Pontian and the Upper Pleistocene of northern China (Teilhard de Chardin & Licent, 1927).

Work in the Sanggan Valley resulted in the discovery of the Nihowan beds, which contained a fauna also intermediate between the Pontian

1884	Birth of Davidson Black on 25 July in Toronto, Canada
1909	Graduation from the Medical School of the University of Toronto
1909 - 1917	First appointment as an anatomist at Western Reserve University, Cleveland, Ohio
1914	Sabbatical leave to England with anthropologist Grafton Elliot Smith, and Amsterdam with neuroanatomist Ariëns Capper
1919	Appointment to the chair of Neurology and Embryology at the Peking Union Medical College in China
1926	Publication of first paper on Zhoukoudian and Peking Man (Black, 1926)
1926 --1934	Publication of 20 papers on Zhoukoudian and Peking Man
1932	Elected Fellow of the Royal Society
1934	Death of Davidson Black on 15 March in Peking, China

Posthumous 1931 Elliot Medal awarded by the National Academy of Sciences for his work on Peking Man

after Sigmon & Cybulski (1981)

Box 3.2 –Davidson Black: A biographical sketch

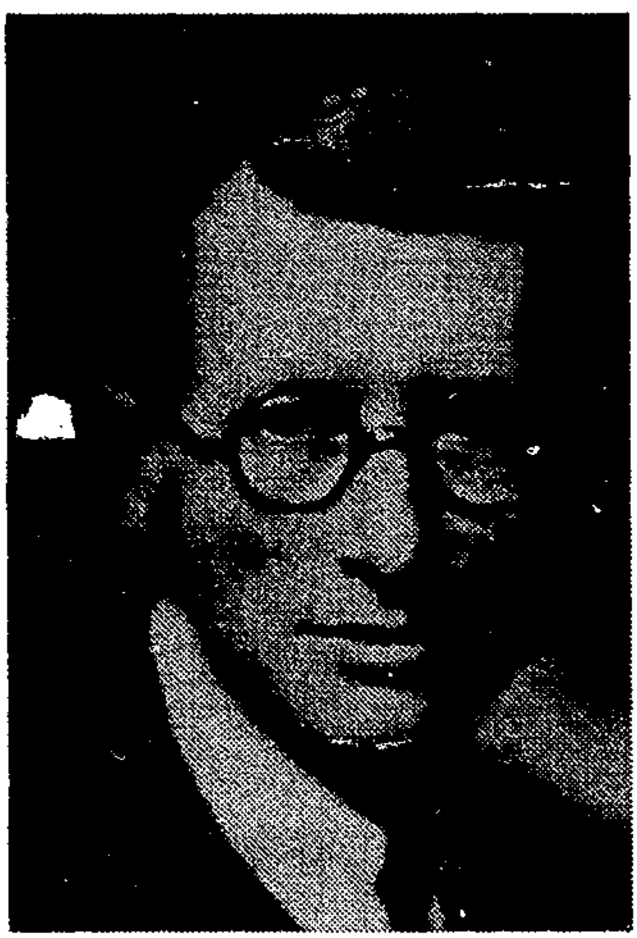


Fig. 3.11 – Portrait of Davidson Black (after Hood, 1964)

1874	Birth of Johan Gunnar Andersson on 3 July in Örebor, Sweden
1898	Nathorst Expedition to Spitsbergen
1899	Expedition to Bear Island in the Barents Sea
1901	Graduation from the University of Uppsala with a doctorate
1903-1906	Nordenskjöld Expedition to the Antarctic
1906	Professor of Geology at Uppsala University and Director of the Geological Survey of Sweden
1910	General Secretary of the 11th International Geological Congress (convened in Stockholm)
1914	Appointment as a mining advisor to the Chinese Government
1914-1926	Work in China (economic geology, palaeontology, ethnology and archaeology)
1926	Return to Stockholm; appointment as a Professor of Geology at the University of Stockholm
1928	Director of the new Museum of Far Easter Antiquities
1934	Publication of Children of the Yellow Earth –Studies in Prehistoric China
1943	Publication of Researches into the Prehistory of the Chinese
1960	Death of Andersson on 29 October.

after Karlgren (1961), Mateer & Lucas (1985), Leroy (1971)

Box 3.3 –Johan Gunnar Andersson: A biographical sketch

Fig. 3.9 – Portrait of Johan Gunnar Andersson (after Karlgren, 1961)

Hipparion fauna and the faunas of the Pleistocene loess formations (Barbour, Licent & Teilhard de Chardin, 1926).

The new expedition to Inner Mongolia, in 1927, led to the compilation of a geological map and a description of the geology and geological evolution of the Weichang region (Teilhard de Chardin, 1932a).

The year 1928 also saw the publication of a report on the post-Palaeozoic eruptions in northern China (Teilhard de Chardin, 1928a) including the Weichang region and the Dalai Nur volcanic centre in Inner Mongolia: Teilhard de Chardin recognised the succession of an intermediate andesitic phase and a rhyolitic phase during the Mesozoic followed in the Late Cainozoic by basaltic volcanism; two tectonic regimes, compressional (Mesozoic) and extensional (Late Cainozoic) were thus identified in northern China.

The research carried out during these first two periods in China provided the material for a theoretical study on the development of continental mammalian faunas (Teilhard de Chardin, 1928b). In this study, Teilhard de Chardin recognised the effect of the alternation of climatic regimes on the formation of the sands/red earths/loess succession in China and on the gradual development of specifically Asiatic faunas (comprising *Moschus*, *Siphneus*, *Gazella* and *Hyaena*). An extensive report on the Palaeolithic of northern China (Boule, Breuil, Licent & Teilhard de Chardin, 1928) comprised a stratigraphic study by Teilhard de Chardin and Licent of the Late Tertiary - Pleistocene succession of red earths, loess and reworked loess, followed by a detailed examination by Teilhard de Chardin and Boule of the mammalian fauna which, they suggested, was very similar to that of the Middle and Late Pleistocene of Europe (with some differences controlled by geography and climate). Breuil described the Mousterian industry and found it to be similar to European types; he recognised the association of the Chinese Mousterian industry with more advanced elements and suggested that Asia might have been a centre of diffusion for this industry.

3.1.3 - The First Peking Period (1929-1930)

The contributions of Teilhard de Chardin to the geology and palaeontology of China led to his nomination in 1929 as a scientific adviser to the Geological Survey of China and his subsequent involvement in geological studies sponsored by the Geological Survey as well as the developing program at Zhoukoudian (for a detailed account of the discovery and development of this site, see Para. 3.3, 3.5 & 3.6): his collaboration with Licent took second place to his work with Chinese scientists, who were frequent co-authors of his papers.

In his first paper on the Zhoukoudian site (Teilhard de Chardin & Young, 1929), Teilhard de Chardin described this Pleistocene fossiliferous fissure deposit where some tooth material of *Sinanthropus pekinensis* Black and Zdansky was found. Two field seasons carried out by the Geological Survey of China and the newly formed Cenozoic Research Laboratory led to the discovery of a fauna containing the giant rhinoceros (*Rhinoceros sinensis*), the sabre-toothed hyena (*Hyaena machairodus*), the fossil dog (*Canis sinensis*) and horse (*Equus sanmeniensis*).

During the summer of 1929, Teilhard de Chardin and C.C. Young (see Box 3.4, Fig. 3.12) travelled to western Shanxi and northern Shaanxi on a Cenozoic Research Laboratory-sponsored expedition to survey the pre-loessic sequences. They recognised (Teilhard de Chardin & Young, 1930) the reddish clays (Sanmenian in age) that lie between the Pontian Red Earths (*Hipparion richthofeni* beds) and the True Loess beds (Middle to Upper Pleistocene).

In 1930, a report was published on the very rich and important Nihowan mammalian fauna collected by Teilhard de Chardin and Licent in the Sanggan He Valley: in this report (Teilhard de Chardin & Piveteau, 1930), Teilhard de Chardin and Piveteau clearly recognised the transitional character of the Nihowan fauna (named after the locality in the Sanggan Valley where it was discovered), which occurs between the earlier Pontian and the later loessic faunas: they assigned it to the Sanmenian stage (latest Pliocene-earliest Pleistocene). The recognition of the Sanmenian assemblage allowed relative ages to be assigned to several sites in northern China, an important

1897	Birth of Yang Zhongjian (C.C. Young) at Huahsien, Shensi, China
1923	Graduation with B. Sc. (Geology) from Peking University
1927	Ph. D. at University of Munich (under M. Schlosser and F. Brolli) and publication of his dissertation on the fossil mammals of North China (Young, 1927)
1928	Return to China
1929	Vice-director of Cenozoic Research Laboratory
1929 – 1934	Zhoukoudian project; study of Cenozoic geology of North China and fossil mammals
1934 – 1938	Study of Mesozoic Reptiles
1938 – 1945	Study of the saurischian fauna in the Lufeng Basin, Yunnan
1945 – 1947	Visit to U.S.A. and Europe and comparative work with museum collections
1949 – 1953	Establishment of the Institute of vertebrate Paleontology, renamed the Institute of Vertebrate Paleontology and Paleoanthropology in 1960, of which he was the founding director
1957	First publication of Vertebrata PalAsiatica, the leading journal of Chinese vertebrate palaeontology
1958	Director of the Peking Natural History Museum
1979	Death of C.C. Young on 15 January in Peking

after Zhou (1979), Sun & Zhou (1991)

Box 3.4 – Yang Zhongjian (C.C. Young): A biographical sketch

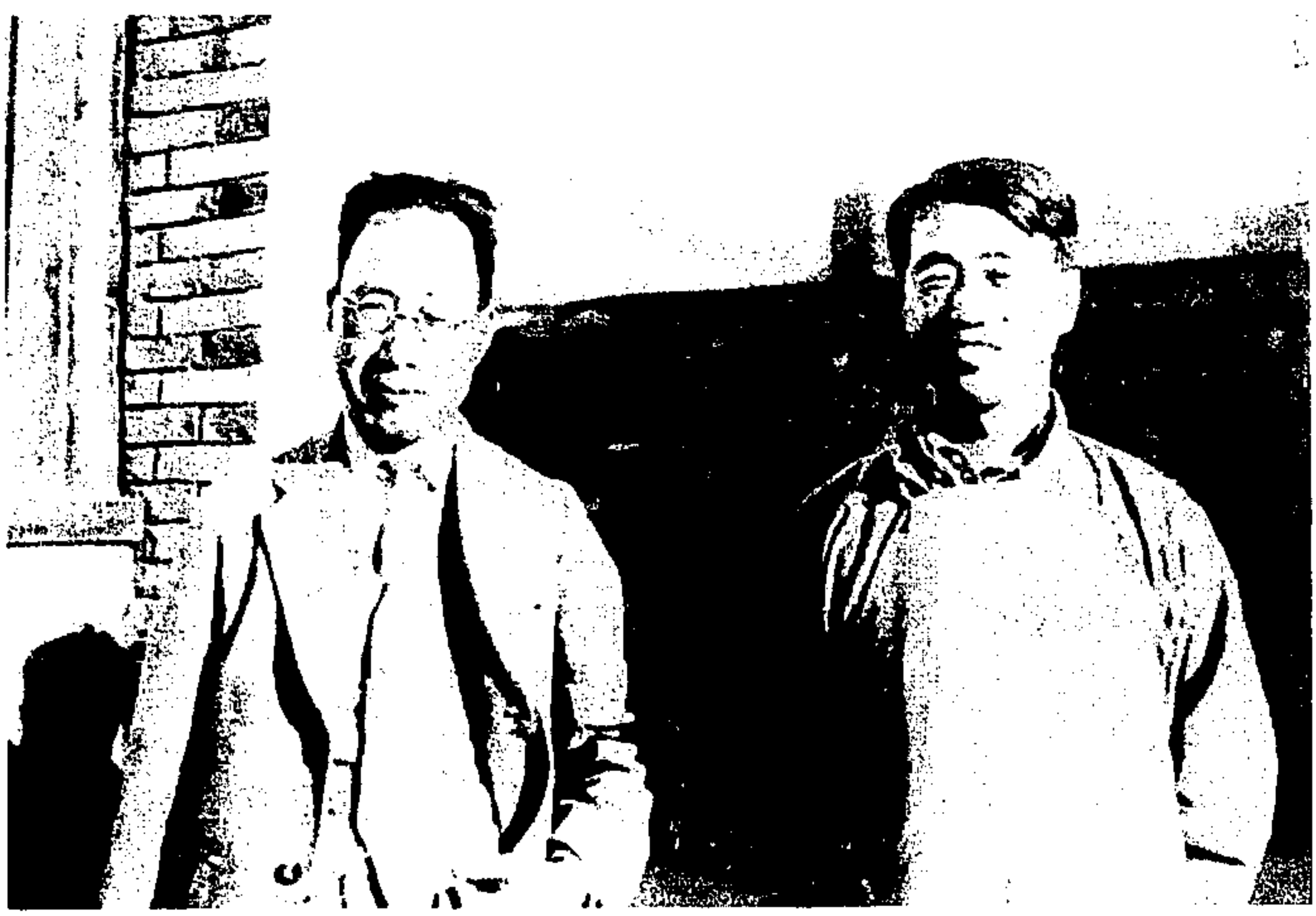


Fig. 3.12 – Yang Zhongjian (C.C. Young) (left) and Pei Wenzhong (right), in 1932 (after Jia & Huang, 1990)

biostratigraphic breakthrough at the time. The Nihowan fauna appeared to be slightly older than the Zhoukoudian assemblage, although the authors attributed the latter fauna to the very end of the Sanmenian.

3.1.4 - The Expeditions: The 1930 Central Asiatic Expedition and the Haardt-Citroen Croisière Jaune (1931 – 1932)

The growing international reputation of Teilhard de Chardin, especially with regard to Chinese Cainozoic geology and palaeontology, led to his participation in the 1930 Central Asiatic Expedition and to the Haardt-Citroen Croisière Jaune in 1931 as an adviser (Fig. 3.3).

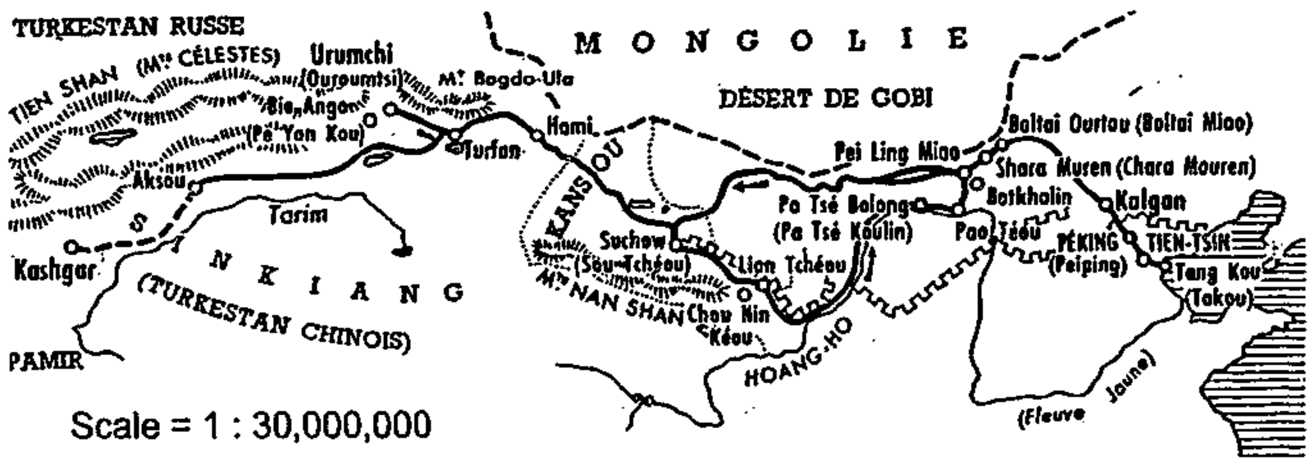
These two expeditions provided the evidence he needed (Teilhard de Chardin, 1932b) to map and correlate the Khangai series of Late Palaeozoic/Early Mesozoic slates with the Lingsi series he had mapped with Licent in the Dalai Nur region. He was also able to recognise the Sanmenian series in Mongolia and to correlate it with the Sanmenian series of other parts of Asia (China, India and Afghanistan), thus providing a stratigraphic framework for the search for fossil hominid remains in this region.

3.1.5 - The Second Peking Period (1932-1936)

During this period, Teilhard de Chardin's work with the Cenozoic Research Laboratory of the Geological Survey of China was mainly concerned with the mapping and correlation of Late Cainozoic deposits throughout China and the description of the Pliocene fauna from the Yushe Basin in south-eastern Shanxi (near Tai Yuan, Shansi). He continued work at the Pleistocene Zhoukoudian locality while furthering his interest in the tectonic evolution of the Asiatic continent through his studies of igneous activity.

In July 1932, Teilhard de Chardin and C.C. Young were sent to southeastern Shanxi by the Cenozoic Research Laboratory of the Geological Survey of China in order to map the Cainozoic deposits. They recognised three stages based on this work (Teilhard de Chardin & Young, 1933): the Pontian and the Sanmenian, both comprising red loams and lacustrine deposits (which

Fig. 3.3 - Route of the Haardt-Citroen Croisière Jaune (after Cuénot, 1958)



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had important implications for the climatic regime in eastern China at the end of the Tertiary) and a Zhoukoudian stage. They suggested that the decreasingly red staining of the loams from the Pontian to the Zhoukoudian stage was a result of climatic change. Licent and Trassaert carried out further work in this area, discovering an important mammalian fauna in the Yushe Basin (near Tai Yuan, Shansi, see Fig. 3.2), which spanned the whole of the Pliocene, from the earliest (Pontian) to the latest (Villafranchian). Much of this fauna was described by Teilhard de Chardin and Trassaert (Teilhard de Chardin & Trassaert, 1937a, 1937b & 1938)

In 1934, Teilhard de Chardin, G.B. Barbour and M.N. Bien travelled to the eastern Qinling Mountains in Henan (Tsin-Ling Shan, Honan, see Fig. 3.2) in order to compare the Cainozoic sequences of the Huang He (Hoang Ho, Fig. 3.2) and Chang Jiang (Yang Tse, Fig. 3.2) basins. They compiled a map of their work (Teilhard de Chardin, Barbour & Bien, 1935), which clearly showed that the axial zone of the Qinling Mountains was made of Palaeozoic granites covered by very thick sequences of Tertiary sediments, in turn overlain by Lower Pleistocene red, banded, concretionary loams. The southern boundary of the Upper Pleistocene loess, widespread in northern China was not visible. Two unconformities (Late Palaeozoic/Early Mesozoic and Pliocene) were recognised.

In 1935, an extensive survey was carried out by Teilhard de Chardin, C.C. Young and W.C. Pei (see Box 3.5 and Fig. 3.12) in Guangxi (Kwangsi, Fig. 3.2) and Guangdong (Kouan-Tong, Fig. 3.2) Provinces in order to map and correlate the Cainozoic formations of the region with those of the Chang Jiang Valley: as a result, a tentative correlation of all Late Cainozoic formations of China was established highlighting major differences between the Late Cainozoic of south and central China on one hand, and the Late Cainozoic of north China on the other.

In 1936, Teilhard de Chardin and Yang surveyed the southern coast of Shandong (Shantung, Fig. 3.2) between Qingdao (Tsin-Tao) and Rongcheng (about 50 km south of Tsin-tao) in order to map the granites and investigate the geological history of this region. This Mesozoic intrusion (Teilhard de Chardin & Yang, 1937) into a thick accumulation of andesites and slates was

1904	Birth of Pei Wenzhong on 19 January
1928	Graduation with B. Sc. (Geology) from Peking University
1929	Discovery of the first Peking Man skull at Zhoukoudian
1933	Discovery of *Homo sapiens* remains in the upper cave of Zhoukoudian
1935	Discovery of Mesolithic implements in Kwangsi (southwest China)
1937	Ph. D. at University of Paris (under Abbé H. Breuil)
1951	Discovery of a skull of *Homo sapiens* in Tzuyang, Sichuan (south-central China)
1954	Discovery of a new Paleolithic assemblage in Tingtsun, Shansi
1955	Member of Chinese Academy of Sciences
1956	Excavations in Kwangsi and recovery of *Gigantopithecus* teeth
1982	Death of Pei Wenzhong on 18 September.

after Boorman & Howard, 1970

Box 3.5 –Pei Wenzhong: A biographical sketch

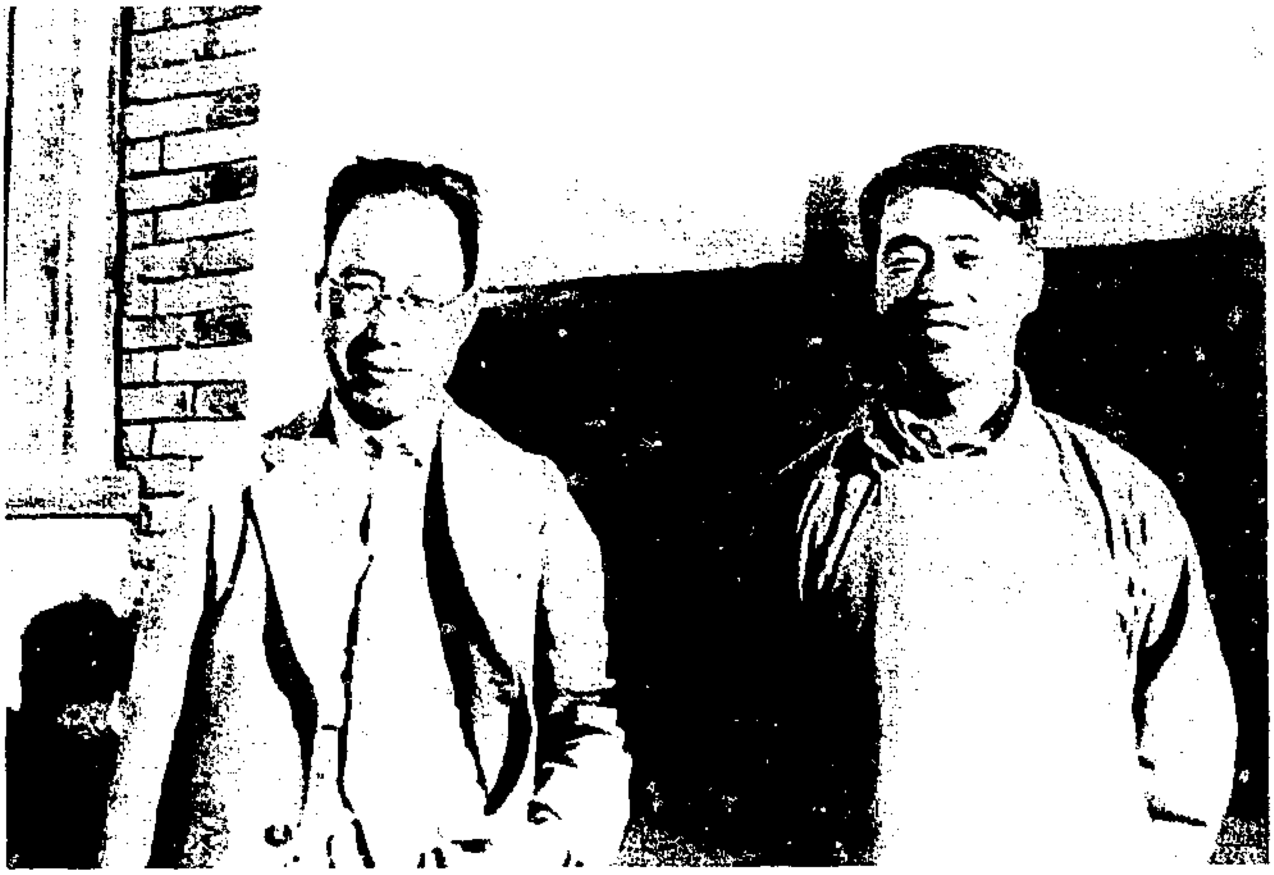


Fig. 3.12 – Yang Zhongjian (C.C. Young) (left) and Pei Wenzhong (right), in 1932 (after Jia & Huang, 1990)

comparable to other intrusions in Manchuria, Jehol (in Manchuria, see Fig. 3.8), Hubei and the Gobi Plateau (Fig. 3.2).

Work on the Zhoukoudian fossil site continued throughout this period: Teilhard de Chardin took over the direction of the Zhoukoudian project upon the death of Davidson Black in 1934. In a review paper published in 1933 (Black, Teilhard de Chardin, Young & Pei, 1933), he described the Zhoukoudian deposit. Teilhard de Chardin felt that it represented a distinct stage in the Late Cainozoic of China, intermediate between the Late Pliocene (Sanmenian) and the Early Pleistocene (Loess). In this paper, he also compared the *Sinanthropus* skeletal remains to other North China fossil hominids and firmly established its hominid status. The cultural remains associated with *Sinanthropus* were also compared with those from cultures in ancient China. Until that date, no Lower Pleistocene sediments had yielded any trace of human occupation, and those associated with the Upper Pleistocene were limited to north China. Holocene Neolithic cultural remains had been collected from Mongolia and Manchuria (the Dune Dwellers), while the Yangshao culture seemed to be restricted to China proper. New discoveries made in Zhoukoudian in 1933-1934 are summarised in a study by Teilhard de Chardin & Pei (1934). Five or six distinct sedimentary units were distinguished in the fissure deposits, showing a transition between an earlier aqueous sedimentary environment followed by a later sub-aerial environment. Short papers were regularly published as fieldwork progressed and new discoveries were made.

3.1.6 - The third Peking period (1939-1946)

After his return to China in 1939 from a stay in France and the U.S., Teilhard de Chardin (Fig. 3.4) found himself forced to stay in Peking because of the Second World War. Fieldwork was impossible, except in the immediate environs. Accordingly, this final Chinese period was one of analysis and interpretation of the material collected previously.

During this period, he established the Peking Institute of Geobiology with Père P. Leroy. The aims of the Institute were two-fold: (1) to act as a repository for the collections and library of the Hoangho-Paiho Museum of Tianjin created in 1915 by Licent (the collections had just been transferred to Peking) and (2) to focus on studies of "continental evolution", which would attempt to trace the joint evolution of rocks and organisms within the framework of the Asiatic continent (Teilhard de Chardin, Leroy, Trassaert & Roi, 1940). A new journal Geobiologia, published by the Peking Institute of Geobiology, started to appear in 1943. The first number included a variety of articles by different authors dealing with the natural history of the Asiatic continent. Teilhard de Chardin's contributions reflect his interests of the period: a philosophical statement about geobiology (Teilhard de Chardin, 1943a) and a lengthy article on the genesis of the Western Hills of Peking (Teilhard de Chardin, 1943b) which showed "on a reduced scale, a peculiar tectonic process (the "flexuration"), which could be regarded as a key mechanism in the whole building of continental Asia". In the second number of Geobiologia, Teilhard de Chardin offered a synthesis of his and others' studies of the geological evolution of the Mongolian Plateau (Teilhard de Chardin, 1945a), some further observations on the geology of the Western Hills (Teilhard de Chardin, 1945b) and a study of the geological structure of the Shimenzhai Basin along the southern border of Manchuria (Teilhard de Chardin, 1945c), another example of the flexuration pattern recognised in the Western Hills.

Teilhard de Chardin left China in 1946 and returned to France where he remained until 1951. During this period, he renewed his contacts with the French scientific community and was elected a member of the Academy of Science. In 1951, he went to New York where, in spite of failing health, he pursued his palaeoanthropological studies under the patronage of the Wenner-Gren Foundation for Anthropological Research until his death in 1955.

Teilhard de Chardin's contribution to Chinese vertebrate palaeontology includes three main components:

- the establishment of Late Cainozoic sequences based on the fossil vertebrate content
- the study of the hominid and mammalian elements of Zhoukoudian
- regional tectonic studies leading to an understanding of the evolution of the Asiatic continent and the implications for the development of the Asiatic fauna.

The range of these interests, and his participation in some of the most important projects during his 23 year-long stay in Asia, as well as his international connections, make him a key figure in the palaeontological community of the time in China.

3.2 – SVEN HEDIN AND THE SINO-SWEDISH EXPEDITION

3.2.1 – Sven Hedin and Central Asia – The Genesis of a Dream

Sven Hedin was born in Stockholm, Sweden, in 1865, the son of the Chief Architect of the City of Stockholm. In his autobiography, Hedin (1991) describes two defining moments in his youth that were to shape his career as one of the most remarkable explorers of Central Asia. The first occurred at age fifteen, when he went, along with his family, to welcome the explorer Adolf Nordenskjöld returning to Stockholm on the *Vega* after an epic journey during which the North-East Passage was discovered. For the next five years, he prepared himself, physically and intellectually, in order to realise his dream of Arctic explorations.

> For as soon as I should be grown up and ready, and a benevolent Maecenas should appear, throwing a bag of gold at my feet, with "Go and find the North Pole!" I was determined to equip my own ship with men, dogs and sleds, and travel through night and ice-fields straight to the point where only south winds blow (Hedin, 1991, p.2).

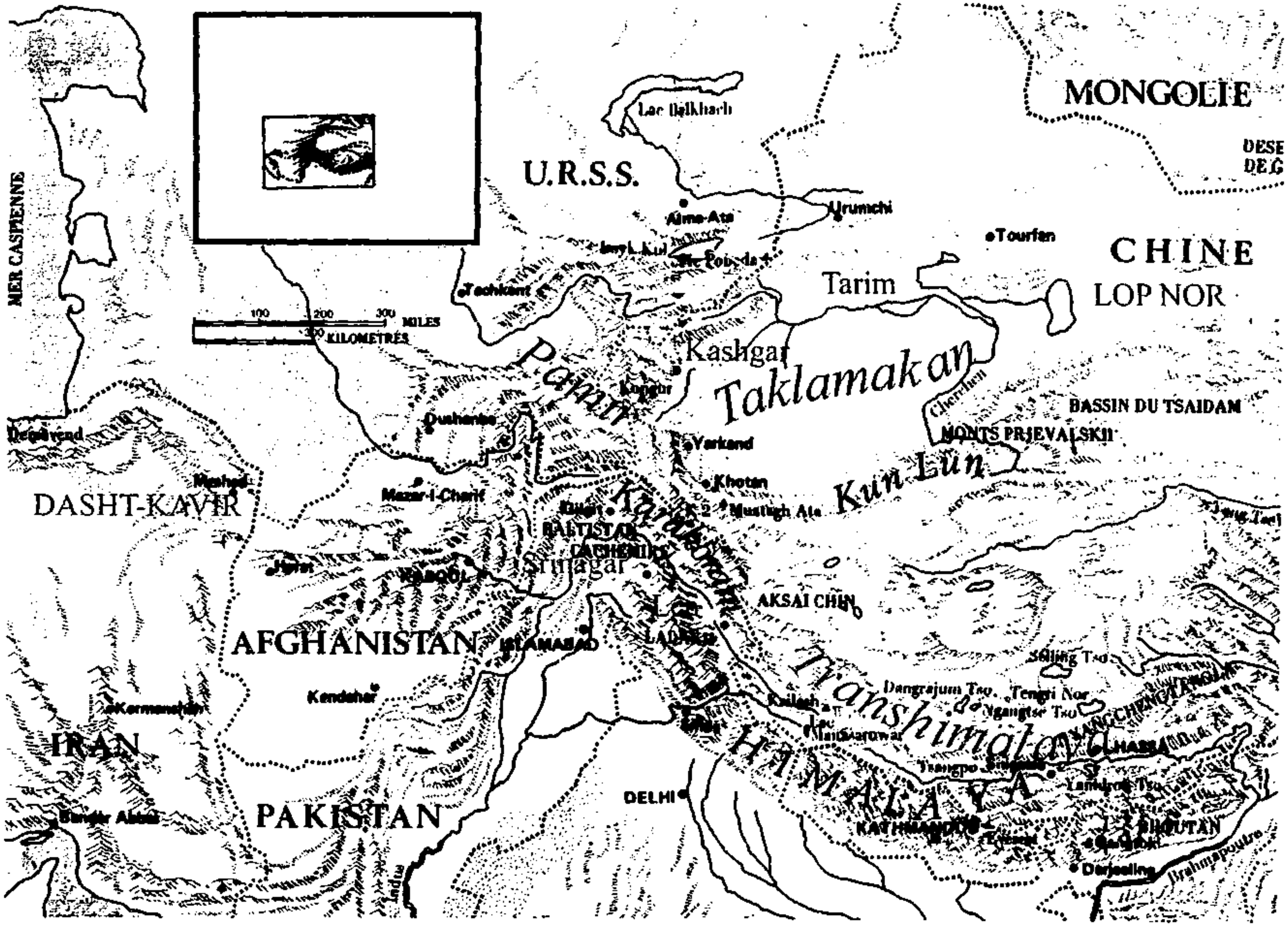
However, five years later, at the end of his secondary studies in 1885, he was appointed tutor to the son of a Swedish engineer, based in Baku, on the western shores of the Caspian Sea and so, according to a biographical account by Gosta Montell, the ethnographer on the Sino-Swedish Expedition (Montell, 1965, p.7), "his dream of the North Pole faded and was replaced by an ardent longing for the Asia that he sensed on the other side of the Caspian Sea". After an 1886 summer trip spanning a large part of Iran and Iraq, he returned to Stockholm (via Baku) and enrolled at the University of Stockholm for geology studies under W.C. Brögger, followed by geography studies in Berlin (1889-1890) at the Institute of F. von Richthofen, an eminent explorer of eastern Asia, who had made major contributions to Chinese stratigraphy, structural geology and geomorphology. In spite of von Richthofen's advice to pursue his geology studies in order to focus on the structure of the eastern Himalayas, Sven Hedin chose to take the opportunity of joining (as an interpreter) the Swedish delegation that was sent in 1890 to the court of the Shah of Persia. Upon completion of the mission, Hedin stayed on in Teheran and started his first expedition to Central Asia, funded in part by King Oscar of Sweden: it took him through Russian Turkestan as far as Kashgar, just inside the Sino-Russian border, where he first came into contact with the Silk Road. He returned to Sweden, completed his studies in 1892 at the University of Halle (Germany) and applied to the King for funds to explore the unknown parts of central Asia, especially the central deserts, parts of Tibet and the Lop-nor district (see Fig. 3.8). His dream was starting to take shape, a dream to the realisation of which he was bringing not only the skills of a geologist and geographer but also language skills: he had a gift for languages and, according to Kish (1988) apart from his native Swedish, he was or became fluent in German, French, English, Russian, Turkish, Farsi, Mongolian and Tibetan. He was also a talented draughtsman and his drawings and maps were to be an integral part of the accounts of his travels.

Between 1893 and 1926, Sven Hedin (Fig. 3.5) led three major expeditions into Central Asia (Fig. 3.6). The first expedition (1894-1897) started from Stockholm, crossed the Pamir Mountains in order to reach Kashgar. From Kashgar, it traversed the sand-covered Taklamakan Desert (twice!), explored the Lop-nor Lake (known as the 'wandering lake'), which was to be of life-long fascination for Hedin, penetrated into Tibet and reached Peking via the Ordos Desert. On his return to Sweden, he published narrative accounts of his travels and scientific reports detailing the results of this expedition and comprising detailed maps drawn by Hedin (Hedin, 1900). The most important results concern the topography and natural history of the Taklamakan Desert, the basin of the Tarim River and Lop-nor Lake; on the ethnographic and archaeological fronts, they include descriptions of the Kirghiz population living in the Kashgar region as well as the Buddhistic culture that flourished in the Taklamakan before the desertification of the region during the past thousand years.

Fig.3.5 – Portrait of Sven Hedin in 1893 (after Kish, 1988)

Fig.3.7 – Portrait of Sven Hedin in 1930 (after Kish, 1988)

Fig. 3.6 – Regional map for Hedin's first three major expeditions into Central Asia, 1893 – 1926 (after Kish, 1988)


MONGOLIE
U.R.S.S.
CHINE
LOP NOR
Tarim
Kashgar
Taklamakan
Pamir
Kun Lun
Transhimalaya
HIMALAYA
MER CASPIENNE
DASHT-KAVIR
AFGHANISTAN
PAKISTAN
IRAN
Lac Balkhach
Urumchi
Tourfan
Alma-Ata
Tachkent
Dushanbe
Mazar-i-Charif
Yarkand
Khotan
Mustagh Ata
BASSIN DU TSAIDAN
MONTS PRJEVALSKII
AKSAI CHIN
ISLAMABAD
Kandahar
DELHI
Srinagar
BALTISTAN
Dangrajum Tso
Tengri Nor
Manasarowar
KATHMANDOU
Darjeeling
Brahmapoutre
Indus
100 200 300 MILES
300 KILOMETRES

The second expedition (1899-1902) started from Kashgar, revisited the Tarim River and the Lop-nor Lake, made several crossings into Tibet, the last of which extended into Leh (Ladakh, see Fig. 3.6) and northern India as far as Srinagar (Montell, 1965). Upon his return to Sweden, he collated the scientific results of the past ten years in Hedin (1904-1907), an eight-volume report written (and drawn) for the most part by Hedin himself with some specialist contributions from other writers.

The third expedition (1906-1908) focused on Tibet where Hedin attempted to map three hitherto unknown regions in the south. The expedition started from Teheran and, on its way to India, mapped large areas of eastern Persia including the Dasht-I-Kavir Desert (Hedin, 1918-1927). While in Tibet, Hedin discovered the source of both the Indus and Brahmaputra Rivers and mapped a mountain chain in southern Tibet, the Transhimalayas (also known as the Hedin Mountains). The results of this expedition were collected in an even more extensive 11-volume publication (Hedin, 1917-1922).

Sven Hedin dedicated the years between 1908 and 1926 to writing, public speaking, political activity and travelling around the world in the course of which he established numerous connections in the political, industrial, academic and aristocratic worlds of many countries. He was now a famous explorer and a respected (and prolific) writer. In 1925, he was approached by Hugo Junkers, an aeronautics engineer, who was trying to develop a worldwide network of air transport and wanted Hedin to advise him on the China-Germany route. As a result, it was decided that the new airline company Deutsche Lufthansa would sponsor a reconnaissance survey on the ground (Kish, 1985, p.127). Thus was initiated the complex program of explorations in north-west China which eventually became known as the Sino-Swedish Expedition.

3.2.2 – The Sino-Swedish Expedition (1926 – 1935) – General description

The following account of the Sino-Swedish Expedition relies, for the most part, on Hedin's narrative, which constitutes a small fraction of a series titled Reports from the Scientific Expedition to the North-Western Provinces of China under the Leadership of Dr Sven Hedin. At the time of Hedin's death (in

1952), 39 volumes had been published in this series: besides Hedin's narrative account (Parts1-3 of History of the Expedition in Asia 1927 – 1935: Hedin & Bergman, 1943a & b and 1944), a separate volume (Part 4 of History of the Expedition in Asia 1927 – 1935: Bergman, Bexell *et al.*, 1945) described the travels and field-work undertaken by the Expedition's archaeologist (Folke Bergman), geologist (Gerhard Bexell), palaeontologist (Birger Bohlin) and ethnographer (Gösta Montell). The other volumes include scientific papers and monographs outlining the scientific results of the Expedition. These will form the basis of my evaluation of the scientific contribution of the Sino-Swedish Expedition.

The Sino-Swedish Expedition can be divided into three distinct periods according to "aims, working program, financial support and membership" (Hedin & Bergman, 1943a, p. XIV). The first expedition (1927 – 1928) was initially a reconnaissance of the Germany - China air route. It was funded largely by Deutsche Lufthansa and included German aeronautical specialists as well as Swedish and Chinese scientists. The focus of the second expedition (1928 – 1933) was scientific and funding came primarily from the Swedish government: sizable donations were also contributed by Deutsche Lufthansa and private individuals. Staff included an equal number of Swedish and Chinese scientists, some German and a few Danish, Russian and Estonian members. The third expedition (1933 – 1935) was funded by the Chinese government which was planning to build a road connecting Xinjiang Province to the rest of China. Even though the primary focus of the first and third expeditions was technical (air and road transport respectively), much scientific work was carried out on the way, in geography & geodesy, geology & palaeontology, archaeology & ethnography, meteorology, zoology and botany.

Arrangements for the first expedition were lengthy and complex: they took the best part of six months and were greatly facilitated by Sven Hedin's fellow Swede, John Gunnar Andersson (see Box 3.3): Sven Hedin arrived in Peking on November 20th, 1926, shortly after the departure of the Crown Prince of Sweden and together with Andersson, he paid a visit to Wong Wenhao, the head of the Geological Survey of China, who recommended that Chinese scientists take part in the Expedition, that all palaeontological results be published in the new periodical Paleontologia Sinica and a proposal be submitted to the Minister for Foreign Affairs, Dr Wellington Koo. Following official approval by the Ministry of Foreign Affairs on 1 January 1927 (see App. 3.1), a contract was drawn up between the Geological Survey of China and the Expedition. This contract, similar to that drawn with Andersson and the Swedish China Committee (see below, Para. 3.3.), stipulated that all finds be kept in China and that three Chinese scientists (two geologists and one archaeologist) be included in the Expedition; consequently, the expedition was known, from then on, as The Sino-Swedish Expedition.

Meanwhile, opposition to foreign expeditions was mounting in some quarters: not only to the Sino-Swedish Expedition, but also to the American Central Asiatic Expeditions led by Roy Chapman Andrews (see below, Para. 3.4), and the work of the Swedish China Committee were targeted; indirectly, the Geological Survey of China was also threatened because of their collaboration with foreign scientists and explorers. According to Hedin and Bergman (1943a), this opposition, arising against the background of an anti-foreign campaign led by Chiang Kaishek's Guomingdang, came from a number of learned societies and universities. As a result, protracted negotiations took place over the next few months and eventually a new contract was drafted, between the "Federation of Scientific Institutions of China" and Sven Hedin, and signed on 26 April 1927 (see App. 3.2).

This contract is very important historically: according to Hedin & Bergman (1943a, p. 52): "Our agreement is in any case the first and probably the last of its kind, and its numerous paragraphs with their far-reaching and ungenerous demands give an interesting picture of the Chinese standpoint of this period", a standpoint framed by the growing nationalism of the turn of the 20th century that led to the fall of the Qing dynasty and the emergence of Chiang Kaishek and his Guomingdang in the 1920's. Chinese historians hail this Scientific Mission to North-Western China as the first equal cooperation between Chinese and foreign scientists, a welcome change after a number of surveys and explorations carried out by scientists and explorers and followed by exportation of specimens and data for use and publication in other countries (Yang, Chen & Yuan *in* Wang, Yang & Yang 1991). Accordingly, the contract provided for two joint field directors, one Chinese and one foreign, under the supervision and direction of a Board of Directors. The composition of the Board of Directors, based in Peking, changed with time but Liu Fu, a French-educated professor of musical acoustics remained its chairman until his death in 1934: he was regarded by Sven Hedin as a "friend, and it was due to him that the relations between the European members of the Expedition and the members of the committee were always characterised by mutual confidence and trust" (Hedin & Bergman, 1943a, p. 55).

The foreign field director was Sven Hedin (Fig. 3.7) for the duration, and the Chinese field director was first Siu Ping-Ch'ang (Xiu Bingxu), a Professor of History and Philosophy followed by Yuan Fuli, an American-educated geologist and archaeologist (Tsing-hua University). All decisions concerning the movement and work schedule of the Expedition were to be decided jointly while dealings with the local authorities and transport were the exclusive responsibility of the Chinese field director. Funding for the Expedition (expenses, salaries and a monthly payment to the Federation) was to be provided by Sven Hedin.

The contract also made detailed provisions for the disposal of specimens and data collected and the publication of preliminary and detailed reports. It distinguished between geological and archaeological materials (Series A) over which tighter control was maintained, and materials associated with the physical sciences such as astronomy and meteorology (Series B).

Eventually, some of the terms of this contract did evolve over time, mostly in response to the changing circumstances, in agreement with the Chinese field directors and without any objection from the supervising Board of Directors who seemed to have "forgotten the existence of an agreement" (Hedin & Bergman, 1943a):

- the Expedition's route eventually encompassed most of central Asia, as far west as Kashgar, parts of northern and western Tibet, Nanshan, the Gobi Desert and Inner Mongolia as far east as Jehol (see Fig. 3.8).
- the duration far exceeded the original two years and, over the three major phases, lasted well into 1935.
- the scientific work carried out by the Expedition became its primary focus (especially during the second expedition), partly as a result of the cancellation of the aviation plans.

- Sven Hedin was able to keep a large part of the prehistorical archaeological material he had collected, since a parallel collection had been amassed by the Chinese field director, and he was able to borrow the historical collections for study purposes after which they were returned to China. The fate of the geological and palaeontological collections is more uncertain with some sections being taken to Stockholm and others left in China with the Geological Survey of China. Some of the material left in China subsequently disappeared during the Sino-Japanese war.

The Sino-Swedish Expedition overlapped in time with the Central Asiatic Expeditions by the American Museum of Natural History. These expeditions took place over a period of ten years, between 1921 and 1930 with five main field seasons (1922, 1923, 1925, 1928 and 1930); they will be dealt with in detail in Para 3.4, but it is interesting at this point to record Sven Hedin's observations about the similarities and differences between the Sino-Swedish Expedition and the Central Asiatic Expeditions (led by Roy Chapman Andrews). One of the main differences and one that irked Roy Chapman Andrews, stems from the fact that Sven Hedin, working independently from any institution, was able to accept the Chinese demands regarding personnel and specimens, which were unrealistic for Andrews as a representative of the American Museum. There are differences in style between the two expeditions: Andrews's was based on a principle of "correlated work" characterised by constant collaboration and interaction between the members of his expedition; this constant interaction was facilitated by the use of motor-cars. In Hedin's expedition, on the other hand, there were different groups working independently in different areas. Transport, in Hedin's expedition, was mostly by camels, much better suited to the deserts and mountains that it encountered. Although Sven Hedin objects to the use of the term "Central Asia" in the title of Roy Chapman Andrews's account of his expedition (Andrews, 1932) in Mongolia (which, technically, belongs to the eastern reaches of Central Asia), he acknowledges and respects the extent of exploration and scientific work carried out in that region and he admits using Andrews's narrative as a model for his own account (Hedin, 1943a, p. 61). Palaeontology was the primary focus of the Central Asiatic Expeditions, which also had had a strong interest in geology, zoology, topography and archaeology and, in that way, the two expeditions had similar interests although the Sino-Swedish Expedition had a much wider brief, taking in meteorology, geography & geodesy, ethnography as well as technical aims such as air and road transport. The two expeditions eventually cost similar amounts.

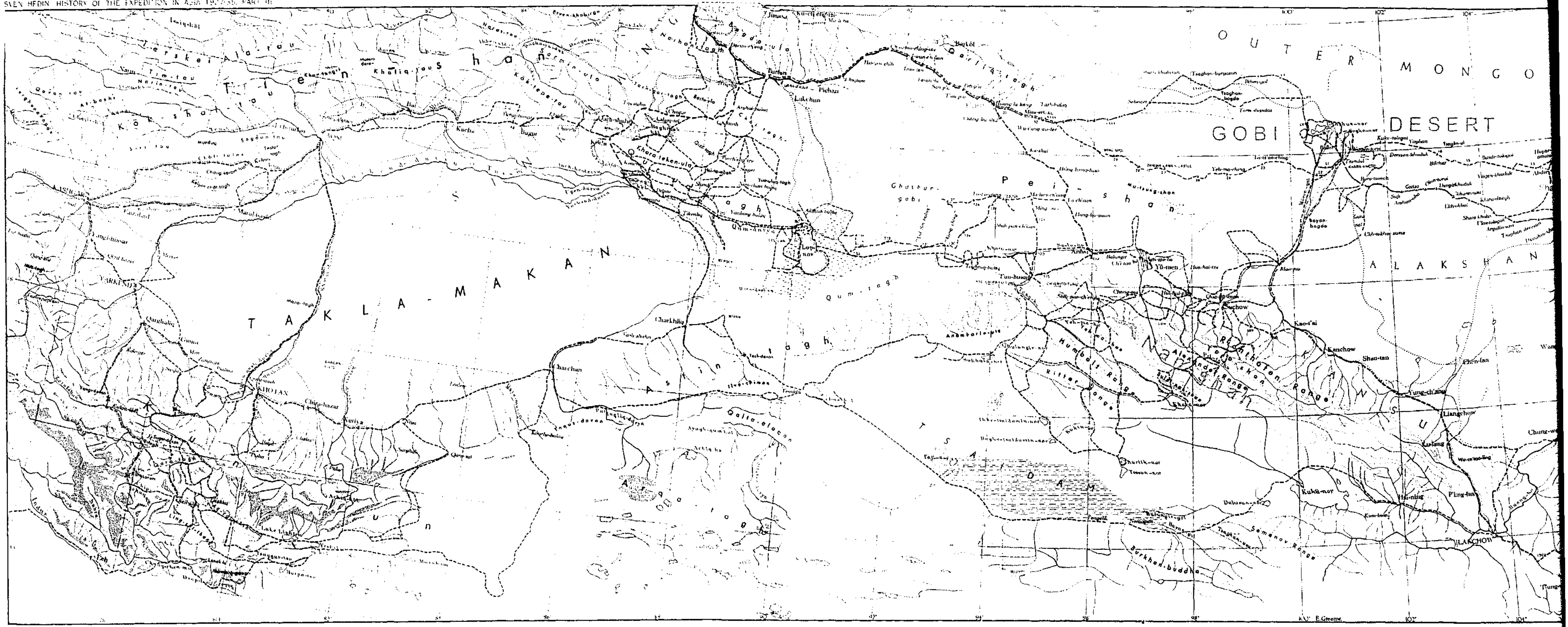
The First Period (February 1927 – May 1928)

The aim of this expedition was, firstly, to map out the terrain in preparation for the development of an airline between Germany and China (Peking/Shanghai) and, secondly, scientific work (in geology, archaeology, meteorology, topography, zoology, botany and physical anthropology). Accordingly, funding was principally by Deutsche Lufthansa and the staff composed of German experts (11) and Swedish (7) and Chinese (10) scientists (Hedin & Bergman, 1943a). The members of the expedition gathered at Pao-t'ou (Fig. 3.8) where the camels were waiting for them at the beginning of May 1927 and, from there, left on a westward route that eventually took them to Urumchi (reached on 29 February 1928) via Khurjitu-gol, Shande-miao, the Edsen-gol and Hami (Fig. 3.8), into the southern reaches of the Gobi Desert and north of the Ordos, the Alakshan and Peishan Ranges (see Fig. 3.8). This phase of the expedition has been described as the last great camel expedition in the classic Style (Montell, 1965, p. 19). The original plan to establish an air route between Germany and China had to be abandoned due to fierce opposition by the local authorities in Xinjiang (Sinkiang, see Fig. 3.3).

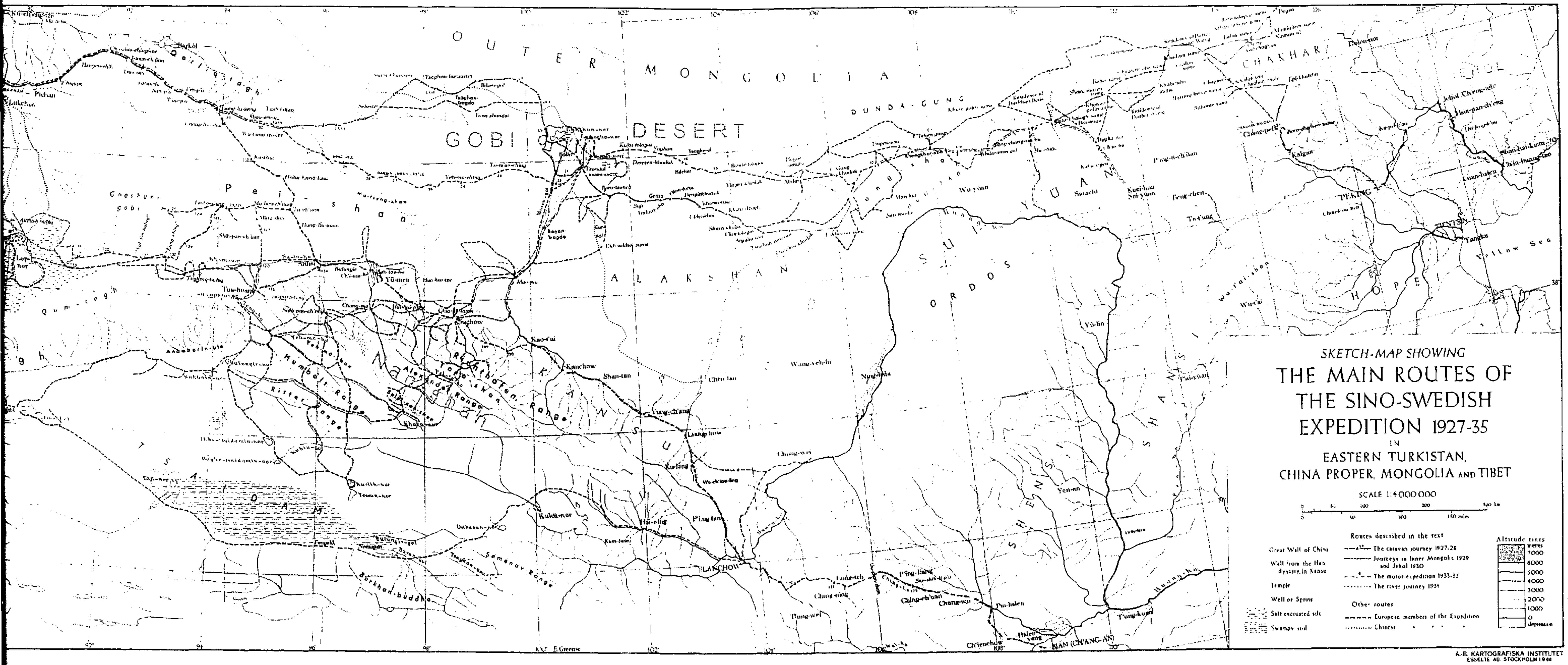
The second period (Summer 1928 –Autumn 1933)

During this period, the focus of the Sino-Swedish Expedition was scientific, and funding was provided by the Swedish Government with additional contributions by Vincent Bendix, Deutsche Lufthansa, Albert Appleton and Sven Hedin. Vincent Bendix, a rich Swedish-American from Chicago, was approached by Sven Hedin, who wanted to put together an

Fig. 3.8 – The main routes of the Sino-Swedish Expeditions (after Hedin & Bergman, 1944)


O U T E R   M O N G O
GOBI
DESERT
A L A K S H A N
T A K L A - M A K A N
Pei-shan
Qum-tagh
Humbolt Range
Ritter Range
Semenov Range
Burkhan-buddha
KHOTAN
YARKAND
Kucha
Turfan
Lukchun
Charchan
Charkhliq
Lop-nor
Anhsi
Tun-huang
Yü-men
Suchow
Kanchow
Shan-tan
Yung-ch'ang
Liangchow
LANCHOW
Kuku-nor
E. Greene

F1



SKETCH-MAP SHOWING
THE MAIN ROUTES OF THE SINO-SWEDISH EXPEDITION 1927-35
IN
EASTERN TURKISTAN, CHINA PROPER, MONGOLIA AND TIBET
SCALE 1:4 000 000
Routes described in the text
The caravan journey 1927-28
Journeys in Inner Mongolia 1929 and Jehol 1930
The motor-expedition 1933-35
The river journey 1934
Other routes
European members of the Expedition
Chinese
Great Wall of China
Wall from the Han dynasty, in Kansu
Temple
Well or Spring
Salt encrusted silt
Swampy soil
Altitude tints
metres
7000
6000
5000
4000
3000
2000
1000
0
depression
OUTER MONGOLIA
GOBI DESERT
ALAKSHAN
ORDOS
SUIYUAN
KANSU
TSAIDAM
CHAKHAR
JEHOL
HOPEI
SHANSI
SHENSI
Pei-shan
Nan-shan
PEKING
TIENTSIN
LANCHOW
Kalgan
Kanchow
Suchow
Liangchow
Yellow Sea
A.-B. KARTOGRAFISKA INSTITUTET
ESSELTE AB. STOCKHOLM 1944

F2

ethnographic collection documenting the practice of Tibetan Buddhism (lamaism) in central Asia; accordingly, a contract was drawn up between Sven Hedin and Vincent Bendix:

> Two lama temples were to be acquired or copied, one for Chicago and one for Stockholm; and both were to be completely equipped with everything in the way of images, cult-objects, textiles, robes, musical instruments etc. that belonged to the interior and exterior decoration. If anything was to be left over from the sum donated it was to be used to purchase ethnographical objects that should be equally divided between the museums of the two cities (Hedin and Bergman,1943b).

Gösta Montell, a Swedish ethnographer was appointed head of the ethnographic division while Gerhard Bexell and Birger Bohlin were in charge of geology and palaeontology. Folke Bergman was the archaeologist of the Expedition (as well as the main editor of publications). This phase of the expedition was characterised by the independent efforts of different groups held together as a 'mobile university' by the leaders. Sven Hedin spent much of the period attending to a variety of commitments in Peking, Sweden, the United States (where he was sent to have a suspected tumour on the spinal chord removed). The geophysicists (Ambolt and Norin) did most of their work in Sinkiang (Xinjiang), while the geologists (Horner, Bexell and Bohlin) and the archaeologist (Bergman) concentrated on the northern Kansu (Kansou, see Fig. 3.3), and the ethnographers (Montell, Haslund and Larson) collected in China and Mongolia (see Fig. 3.8).

The third period (1933 –1935)

The third phase of the expedition was born out of a chance meeting between Sven Hedin and Liu Chungchieh, Assistant Foreign Minister in Chiang Kai-shek's Nanking Government, at the German Legation (28 June 1933). There was, at the time, great concern in China about the separatist tendencies of Sinkiang (Fig. 3.3). The Minister was very interested in Sven Hedin's recent experiences in Sinkiang and Chinese Turkestan and in response to the Minister's question about the best way to hold on to Sinkiang, Sven Hedin suggested:

> I think the first step that ought to and can be taken is to make and maintain first-class motor-roads between China proper and Sinkiang. A railway line into the heart of Asia is the next step (Hedin & Bergman, 1943b, p. 209)

The project was eventually financed by the Chinese State, which requested that a suitable route for two motorcar roads between China and Sinkiang be investigated. The expedition was to include Swedish and Chinese members and was able to carry out archaeological, zoological, botanical and geographical work as well (see Fig. 3.8).

Sven Hedin's account of his years on the road shine with the strong bond he established with the people and landscapes of China and Central Asia. In his concluding statement, he reviews the extremes of topography, climate and environments he and the expedition encountered. Throughout his travels in some of the most remote places on the Earth, he was sustained by what he came to call the "pleasure of isolation" and the daily cycle of moving, working, resting and occasionally meeting other sedentary or nomadic inhabitants of the region. Two quotes illustrate this beautifully:

> These desert meetings remind one of passing ships that meet on the open sea and send each other a greeting over the waves.......Skeletons are the wrecks of desert ships (Hedin & Bergman, 1943a, p. 121).

> I cannot imagine anything more splendid than to build my airy habitation in a different spot every day, and to study the earth's surface, not in a text-book but in reality. And then, however instructive the day has been, evening always comes as a solace and a relief (Hedin & Bergman, 1943a, p. 122).

And a third quote, summing up his experiences and work during the Sino-Swedish Expedition, highlights the difficult conditions created by human affairs and contrasts them with the enduring presence of the Earth which transformed his wanderlust into a lasting body of work:

> Our years in Asia passed all too quickly, leaving us with a rich store of ineffaceable memories. We remember the dangers that threatened us daily in the period when civil wars were raging in North China, Mongolia and Sinkiang. But kindly

stars shone over our paths and we remember, too, periods of years when we enjoyed the profoundest peace and the most undisturbed working atmosphere.

Now, as the wings of time increase the distance between the past and the present, news very occasionally seeps through to our ears of the great changes that have taken place in the tracts where we spent so many happy years. But however fundamental and violent may be the revolutions that in our time are celebrated by all peoples and states like some huge saturnalian orgy, our old earth remains untouched (Hedin and Bergman, 1944, p. 311).

3.2.3 – The Sino-Swedish Expedition (1926 – 1935) – Scientific results

A survey of the available reports published in the series of Reports from the S[illegible]ntific Expedition to the North-Western Provinces of China under the leadership of Sven Hedin (Editor: G. Montell) shows the following distribution by subjects (see Table 3.1):

Archaeology: 8 reports
Ethnography: 8 reports
Geodesy: 2 reports
Meteorology: 2 reports
Botany: 4 reports
Geology: 8 reports
Palaeobotany: 1 report
Invertebrate Palaeontology: 3 reports
Vertebrate Palaeontology: 6 reports

Total: 42 scientific reports (these 42 added to the 4 reports devoted to the history of the expedition add up to a total of 46 reports. These (out of a general total of 54 published) were all sighted by the author; the remainder was not available).

All of the contributions in the field of vertebrate palaeontology were written by Birger Bohlin; Bohlin had completed his doctoral thesis in Uppsala University on the subject of fossil Giraffidae from China (based on material collected by J.G. Andersson) before travelling to China in 1927 where he supervised the excavations at Zhoukoudian (see Para. 3.6). He joined the Sino-Swedish Expedition in 1929 where he carried out geological and botanical as well as palaeontological studies. He returned to Sweden in 1933 where he spent the remainder of his life describing the material he had collected (Mateer & Lucas, 1985). Thirty-five papers by Bohlin are listed in Georef (the latest, about the excavations at Zhoukoudian, was published in 1980). Schöbel (1985) lists 42, all but one authored singly, and the latest listed here is 1978.

In the papers describing the material he collected in Kansu Province, Bohlin alludes to the challenges of collecting, locating and dating the specimens in areas that had not been mapped before, even topographically, and mourns the fragmentary and poorly preserved quality of the specimens, especially when compared with the material collected by the Central Asiatic Expedition in Mongolia (see Para. 3.4). One of the most important localities he studied was the Tertiary deposit of Taben-buluk (south of Tunhuang, western Kansu, see Fig. 3.8), where he described a suite of Tertiary mammals including Insectivora, Lagomorpha, Simplicidentata, Carnivora, Artiodactyla, Perissodactyla and Primates (Bohlin 1942 and 1946). He was able to draw comparisons with other Asian localities primarily on the basis of the genus *Sinolagomys* (Saint Jacques, described by Teilhard de Chardin, and Hsando-gol from which material was collected by the Central Asiatic Expedition; both localities are about 1,000 km away from Taben-buluk).

Bohlin also described some reptiles from the Late Mesozoic badlands in Mongolia and Kansu, among which figure 15 different species of dinosaurs, several of them new species and 5 genera of turtles. Bohlin also contributed 3 geological studies to the report series, reflecting the need to establish a geological framework in order to interpret the fossil remains.

A recent evaluation of the achievements of the Sino-Swedish Expedition by Chinese scientists (Yang, Chen & Yuan *in* Wang, Yang & Yang, 1991) highlights the installation of meteorological stations in Xinjiang, the geographical location of Lop-nor Lake (the lake is located between the Taklamatan and the Gobi Deserts; its precise location had been in dispute and the subject of a life-long fascination for Sven Hedin), and the collection of mammal-like reptiles by Yuan Fu Li (the Chinese leader of the Expedition and a geologist). The emphasis on meteorology harks back to the aeronautical origins of the Sino-Swedish Expedition; the meteorological stations were manned by six young Chinese meteorologists under the supervision of Waldemar Haude, a German meteorologist; two of the Chinese meteorologists went on to further study in Germany and one of those two, Li Xianzhi (who later became a Professor of Meteorology at Peking University), wrote a seminal thesis on the movement of cold air masses in Central Asia, based on a comparison of the measurements he had made in Xinjiang, with those of surrounding regions.

The discovery, by Yuan Fu Li of 72 skeletons of mammal-like reptiles including 8 new species of *Dicynodon* (1), *Lystrosaurus* (3), *Chasmatosaurus* (1), *Santaisaurus* (1), *Tianshansaurus* (1) and *Pinacosaurus* (1), was important on several grounds. Firstly, they were the first group of mammal-like reptiles to be found by Chinese scientists and kept in China; secondly, the presence of *Dicynodon* and *Lystrosaurus* in the Permian of Xinjiang provided another locality to those already known at the time (Karroo Basin in South Africa and Indochina) allowing a better understanding of the origin and distribution of this group as well as adding yet another piece of evidence to support the theory of continental drift).

The important contribution made by the Sino-Swedish Expedition in the fields of archaeology and ethnography is beyond the scope of this thesis; it is on a par with (and often on the steps of) that of the Hungarian-born Aurel Stein, one of the greatest orientalists whose collections gathered in western China, Chinese Turkestan and central Asia can now be found in the British Museum. The ethnographical collections of the Sino-Swedish Expedition, financed by that generous Swedish American, Vincent Bendix, are now housed in the Ethnographical Museum of Sweden along with the entire personal archives of Sven Hedin (Linné, 1965).

3.3 – JOHAN GUNNAR ANDERSSON: AN ECONOMIC GEOLOGIST WITH A DIFFERENCE

According to Mateer and Lucas (1985), the history of Swedish interest in the fossil record of China (and of the Axel Lagrelius Collection in the

Palaeontological Museum of the University of Uppsala, one of the largest repositories of Chinese fossil vertebrates outside China) starts in 1914 with the arrival in China of John Gunnar Andersson (see Box 3.3 and Fig. 3.9). Following an agreement between the Chinese and Swedish governments aiming at the exploration and exploitation of Chinese ore deposits, J.G. Andersson, the Director of the Geological Survey of Sweden, had been invited as a mining adviser by the Chinese government.

Andersson described himself, in the account of his years in China which he wrote for the general public (Andersson, 1934), as a "mining specialist, a fossil collector and an archeologist". Andersson's activities soon expanded from the field of economic geology: in the course of numerous field trips to the provinces, inspecting mining operations, he started to collect fossils and artifacts. Andersson had read Schlosser's review of the mammalian fossil record of China and wrote to Christian missionaries and foreign residents asking for help to locate fossil ("dragon bones") localities.

Andersson set in motion what was to become a very important Sino-Swedish collaboration when he advised V.K. Ting, the director of the Geological Survey of China to send a large collection of fossil plants from Sichuan and Yunnan to T.G. Halle, a palaeobotanist at the Swedish Museum of Natural History. Halle subsequently came to China to collect more material and worked with a Chinese geologist, Chow from the Geological Survey of China.

Andersson also became interested in dating the loess deposits first identified by Richthofen (who had undertaken the first scientific expedition on a grand scale of China and Central Asia between 1868 and 1872) and suggested using vertebrate assemblages for dating these deposits. He contacted Carl Wiman, a vertebrate palaeontologist at the University of Uppsala, Sweden. Wiman undertook to work on the material collected by Andersson and sent him an assistant, Otto Zdansky, an Austrian vertebrate palaeontologist, who had just spent six months in Uppsala working with Wiman.

By the beginning of the 1920's, Andersson's ethnographical, archaeological and palaeontological activities were taking up an enormous amount of his time, and a special agreement had to be established with the Geological Survey of China. He negotiated a contract for 1924-1927 whereby he continued in his capacity as an advisor but donated his salary to start a fund dedicated to the description and publication of the material he had collected in a monograph series, Paleontologia Sinica. Paleontologia Sinica was published by the Geological Survey of China under the editorship of V.K. Ting (Director of the Geological Survey between 1916 and 1926), Wong Wenhao (Director of the Geological Survey of China between 1925 and 1935) and Andersson. The monograph series comprised three parts:

- Series A: Fossil plants (Special editor: T.G. Halle)
- Series B: Invertebrate fossils (Special editor: A.W. Grabau)
- Series C: Vertebrate fossils (Special editor: C. Wiman)

Halle and Wiman have already been introduced in this narrative. Grabau was an American geologist, who had been appointed a Professor in the Department of Geology at the University of Peking as well as the Chief Palaeontologist at the Geological Survey of China.

The contract between Andersson and the Geological Survey of China included provisions concerning the conservation of specimens. Fossil vertebrates were to be sent to Wiman at the University of Uppsala and fossil plants were to go to Halle at the Swedish Museum of Natural History in Stockholm. Duplicates of vertebrate and plant fossils were to be made and sent back to China. All fossil invertebrates were to stay in Peking, although Grabau made duplicates, which he sent to Stockholm in exchange for duplicates of Swedish invertebrates. Andersson became the Curator of the Museum of the Geological Survey of China in 1921.

This arrangement had international repercussions. The American Museum of Natural History expedition was excluded from "geological, palaeontological or archaeological explorations in Northern China" (Andrews, 1932, p. 572), which, in fact, restricted them to Mongolia. The French Jesuit, Licent was also developing a museum in Tianjin and had no desire to hand over his material to the Geological Survey of China. He called on Boule and Teilhard de Chardin to describe his material in a special volume of Paleontologia Sinica. As a result of this agreement, Sweden had exclusive rights to the Chinese fossil record in 1921.

Upon the arrival of Otto Zdansky in China, Andersson decided to a send him to a site that had been pointed out to him three years earlier by his friend J.

McGregor-Gibb who was teaching chemistry in Peking. The site was Jigushan (Chicken Bone Hill, near Zhoukoudian).

According to Mateer and Lucas (1985), Andersson visited Zdansky in August 1921 with Walter Granger, the Chief Palaeontologist of the Third Central Asiatic Expedition led by Roy Chapman Andrews. Granger had just taken up his position, and Andersson took him up to Zhoukoudian to acquaint him with Chinese conditions and hear of a new excavation technique that Granger had developed. While they were there, a local resident approached them to tell them of another place where they could collect "much larger and better dragon bones". In this new site, they found remains of the thick-jawed deer *Megaloceros pachyosteus*, rhinoceros, hyaenas and bears, as well as stone tools, which led Andersson to believe that this was a hominid site (Jia & Huang, 1990). This intuition turned out to be correct, as the first human tooth was collected by Zdansky at the end of the season from that site.

The discovery of the Zhoukoudian site in which Peking Man was found (see Para. 3.5) ranks foremost among the achievements of Johan Gunnar Andersson; Andersson also contributed significantly to the Neolithic Archaeology of China, principally from the provinces of Honan and Kansu (the Yang Shao culture), as well as the early historical culture of China and the interpretation of bronze artifacts (Leroy, 1971).

3.4 – THE CENTRAL ASIATIC EXPEDITIONS (1916 – 1930)

3.4.1 - The Central Asiatic Expeditions (1916 – 1930)– Narrative

"The fossils are there, I know they are. Go and find them." (Andrews, 1929, p. 268). Osborn's injunction to Roy Chapman Andrews, the leader of the Central Asiatic Expeditions launched by the American Museum of Natural History was all the more needed as some critics suggested they had as much chance of finding fossils in the Gobi Desert as in the Pacific Ocean (Andrews, 1932, p. 7) Why was the Gobi Desert chosen as a destination rather than northern China where tantalising finds had been made, suggesting that the fossil record would yield much information about the evolution of mammals including man? The answer is two-fold: (1) "...an agreement had been entered into between the Geological Survey of China and the Central Asiatic expeditions that the Expeditions would not enter upon geological, palaeontological or archaeological explorations in northern China" (Andrews, 1932, p.572). (2) after having led the First Asiatic Expedition (1916-1917) to the Province of Yunnan, southwest China and to the borders of Tibet and Burma, Andrews spent several months in northern Mongolia where he collected mammals for the American Museum of Natural History. This Second Asiatic Expedition took place during the summer of 1919, and it was an opportunity for Andrews to become acquainted with the region and to develop a plan to deal with the large distances and the remote and harsh character of the region. This plan involved the use of motor cars instead of the caravans of camels, mules or yaks traditionally used in the region. On his return to New York, he presented his plan to Osborn, then President of the American Museum of Natural History and outlined the main aims of the Expedition:

> The main problem was to be a study of the geologic history of central Asia; to find whether it had been the nursery of many of the dominant groups of animals, including the human race; and to reconstruct its past climate, vegetation and general physical conditions, particularly in relation to the evolution of man (Andrews, 1932, p. 5).

Osborn received the plan enthusiastically, because it was a chance to confirm the biogeographical ideas he had developed in *The Age of Mammals* (Osborn, 1910), and the palaeoanthropological dimension of the project opened new opportunities. Such an expedition was also likely to have enormous popular appeal: this, in turn, would make the promotion and funding of the expeditions much easier. Many of Osborn's business friends and patrons were interested in the opportunities offered by Asia in the context of the establishment of the Open Door policy in China in 1899 (Rainger, 1991).

The initial proposal, planning, organisation and fund-raising were very much the brainchild of Roy Chapman Andrews, although it had the full support and backing of Henry Fairfield Osborn, the Head of the Department of

Vertebrate Palaeontology as well as President of the American Museum of Natural History.

The aims of the Second Asiatic Expedition had been three-fold: (1) to become better acquainted with the Mongolian conditions; (2) to carry out zoological work which resulted in the collection of mammals representing three faunal areas; (3) to form a basic plan for the subsequent expeditions which became known as the Central Asiatic Expeditions of the American Museum of Natural History.

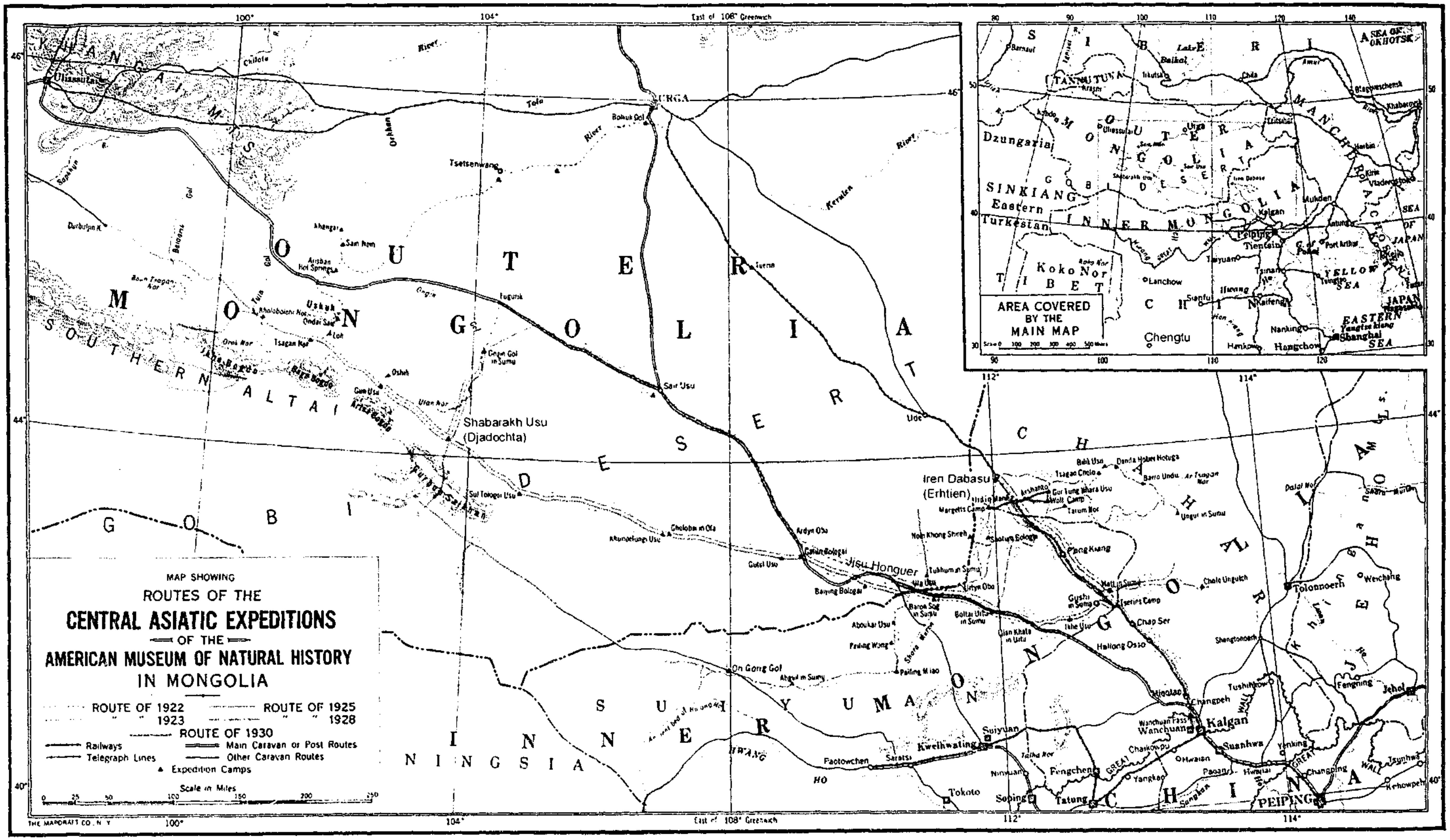
> We were to bring upon our problem every branch of science which could possibly assist in its solution. Moreover, these sciences must be represented by men of the highest scientific ability. We must take the men into the field *together*, so that each would have the advantage of assistance from the others; *correlated work* was to be the basis of the scientific organisation. Motor cars were to be used in conducting the exploration while a caravan of camels transported the supplies to specified locations. This procedure would give us the great advantage of speed over previous explorers. Headquarters were to be established in Peking, where the Expedition was to be prepared for actual field operations and where the complicated diplomatic and administrative work could be carried on (Andrews, 1932, p. 5).

Eventually, the Central Asiatic Expeditions included seven field seasons (1916, 1919, 1922, 1923, 1925, 1928 and 1930) and were finally brought to a halt as a result of increasing political tensions within China and the opposition of the Society for the Preservation of Cultural Objects (later known as the National Commission for the Preservation of Ancient Objects). Total funding for the Expeditions came to $500,000 and was provided by the American Museum of Natural History, the Field Museum and 383 individual contributors, American and foreign (Osborn, 1930).

The Third Asiatic Expedition took place during the summer of 1922 and was conceived as a season of reconnaissance of the region as a whole (see Fig. 3.10) and, accordingly, the number of specialists was small. Table 3.2 shows the personnel and equipment used in this Third Expedition, a much more formal arrangement than that of the preliminary Second Expedition which was characterised by a friendly and informal character (Table 3.3).

The Fourth Asiatic Expedition (1923) aimed at exploring the rich fossil

Fig. 3.10 – Routes of the Central Asiatic Expeditions, 1922-1930 (after Andrews, 1932)



Route map of the Central Asiatic Expeditions, 1922 - 1930.

fields that had been discovered, and accordingly, three more palaeontologists, George Olsen, Peter C. Kaisen and Albert F. Johnson as well as two trained Chinese assistants were selected to assist Walter Granger, the Chief Palaeontologist.

During the Fifth Asiatic Expedition (1925), a palaeobotanist (Ralph Chaney) and an archaeologist (Nels Nelson) were added to the team in order to provide palaeobotanical confirmation of the climatic cycles that had taken place in Central Asia since the Jurassic and to search for evidence of early human occupation. These changes reflect the changing concerns of successive expeditions and the use of what Andrews termed "the method of correlated work".

The Sixth and Seventh Asiatic Expeditions (1928 and 1930 respectively) included the same representation of scientific disciplines, although these were sometimes represented by different individuals. The Seventh Expedition is notable for its inclusion of Chinese representatives among the scientists as well as the participation of P. Teilhard de Chardin. The two Chinese representatives were Prof. S.C. Chang and Dr C.C. Young, both of whom had been delegated by the Commission for the Preservation of Ancient Objects. C.C. Young was attached to the Geological Survey of China, while S.C. Chang was a Professor of Geology and Palaeontology at Sun-Yat-Sen University, Canton. In the course of the Expedition, C.C. Young was replaced by W.C. Pei, also of the Geological Survey of China; both men were then at the beginning of significant careers as Chinese palaeontologists and will figure prominently in the remainder of this account of the development of vertebrate palaeontology in China.

Table 3.4 shows a composite list of all scientific and technical staff in the Central Asiatic Expeditions between 1921 and 1930. This list reflects the geological and palaeontological focus of these expeditions: five geologists and eight palaeontologists took part under the supervision of Charles P. Berkey (Chief Geologist) and Walter Granger (Chief Palaeontologist) respectively. Overall, five topographers were required (under the supervision of L.B. Roberts in order to map the unexplored terrain). One zoologist, two archaeologists and one herpetologist participated. Special note must be made of the presence of Amadeus W. Grabau and Teilhard de Chardin. Professor A.W. Grabau (1870 -

1946) was an American geologist and palaeontologist who, after having spent the first half of his career as a prominent geologist and palaeontologist in the U.S., became a Professor of Palaeontology at Peking University and Chief Palaeontologist at the Geological Survey of China; from 1922 to 1930, he was associated with the Central Asiatic Expeditions, not in the field but as a research associate. Besides numerous scientific papers on Chinese stratigraphy and invertebrate fossils published elsewhere, he contributed a monograph, The Permian of Mongolia to the Central Asiatic Expeditions Publication Series (Grabau, 1931). Teilhard de Chardin, who has already been introduced in this narrative (see Para. 3.1), was also seconded from the Geological Survey of China. These two scientists, along with Johan Gunnar Andersson (who was also associated in a less formal manner, with the Central Asiatic Expeditions), form the central triangle around which the whole palaeontological endeavour in the region seems to have turned.

Besides the main Mongolian expeditions described above which took place mostly during the summer, a series of specialised explorations were undertaken in the Chinese territory in between the major expeditions. They were:

- a search for the takin (*Budorcas*, a rare bovid with a 'golden fleece', found in western China and Assam), led by Andrews in 1921
- several herpetological expeditions to northern and central China (1921 – 1922), to Hainan Island (1922 – 1923) and to Fukien and Kiangsi Provinces (1925 – 1926), led by Clifford Pope.
- several palaeontological expeditions to eastern Szechwan (Wanhsien and Yen-ching-kou) during the 1921 – 1922, 1922 – 1923 and 1925 – 1926 winters, led by Walter Granger. The Yen-ching-kou locality turned out to be of importance for its Pleistocene fauna. According to Granger (*in* Andrews, 1932, p. 528):

> The collection is important not only in giving a picture of the life of this particular region, but, being midway between fossiliferous deposits of the same age in north China and northern India, it helps greatly in working out the general distribution and migrations of mammalian life in eastern Asia during the Pleistocene period.

- Granger also led a reconnaissance to Yunnan along with archaeologist Nelson during the winter 1926-1927, when a Pleistocene locality (Ma Kai) was discovered.

3.4.2 - The Central Asiatic Expeditions (1916 – 1930) – Results

The five field seasons of the Central Asiatic Expedition of the American Museum of Natural History were to lead to the discovery of a new biogeographic region, Gobia. According to Reeds (*in* Andrews, 1932, p. 565), "An old continent new to science, the continent of Gobia as A.W. Grabau calls it, was discovered". The Gobi Desert constitutes a central depression within the Mongolian Plateau and contains minor basins known as talas. Talas, in turn, contain smaller basins called gobis, which are frequently covered by Mesozoic or Tertiary sediments, where most of the fossil localities were discovered. The region is characterised geologically by the presence of pre-Cretaceous bedrock, which has undergone extensive deformation and associated igneous activity. The bedrock is overlain by Cretaceous and Cainozoic undeformed sediments. A major unconformity lies between the bedrock and the overlying sediments.

According to Reeds (*in* Andrews, 1932), palaeoclimatic evidence indicates that, while the climate was mostly temperate at the end of the Palaeozoic, it became warmer and wetter during the Jurassic. The Cretaceous saw an increase in aridity. During the Tertiary, the emergence of the Himalayas had a profound influence on the climate of the region, which acquired a desert-like character. During the Pleistocene, an alternation of cold-moist and warm-dry climatic regimes took place, leading to an increasingly drier regime during Recent times.

The palaeontological discoveries made in the region were based on careful stratigraphic work on the younger sediments: 39 formations were recognised and, among them, 15 were to prove fossiliferous, spanning most of the Cretaceous and Cainozoic. The known fossil vertebrate record of the Asiatic region was thus extended from the Pliocene back to the Cretaceous. A Palaeozoic invertebrate fauna recognised in the Jisu Honguer limestone beds of southern Mongolia indicated that the region was invaded by the sea during the Permian. These discoveries were rich ones as demonstrated by the fact that, between 1923 and 1932, 51 papers on the palaeontology of the region were published in which 218 different organisms were described. Four new families, 2 new subfamilies, 64 new genera, 148 new species and 1 new variety were recognised. Some of this fossil material is especially significant:

- the Cretaceous dinosaur fauna: the dinosaurs found in the Iren Dabasu Formation were the first evidence of Cretaceous fauna in the region and the first dinosaurs found in Asia. They included duck-billed iguanodonts, the small ostrich-like *Ornithomimus* and carnivorous *Deinodon*. This formation is also a secondary locality for dinosaur eggs. The main locality for the famous discovery of dinosaur eggs is the Djadochta Formation in the Flaming Cliffs of Shabarakh Usu (western Mongolia, see Fig. 3.10): this major discovery not only demonstrated that dinosaurs laid eggs but also, because of the quantity of eggs, that the region was a breeding ground for dinosaurs.

- the Cretaceous mammalian fauna: the remains of 11 individuals were collected from the Djadochta Formation, belonging to three families: Ptilodontidae (Multituberculata), Deltatheridiidae and Zalambdalestidae (Insectivora). Five new genera were created for them. This find was especially significant since the only Mesozoic mammal known to-date (1925) was a multituberculate skull named *Tritylodon*, from the Triassic of South Africa. The new Mongolian finds, especially the Insectivora, constituted a genuine missing link in mammalian evolution. According to G.G. Simpson (1928):

> Not only are these remains by far the most complete ever discovered in the Mesozoic, but they also occupy a very strategic position in time and in space which makes close scrutiny of the relationships essential. In time they occur in the Cretaceous when, according to theories formed before their discovery and based largely on early Tertiary mammals, the differentiation of placental orders should be in progress and not yet far advanced. In space, they occur in central Asia in or near the region which a number of students, especially Osborn and Matthew, have considered an important center of radiation, and probably the very one from whence came the groups of mammals which appear to have entered North America and Europe suddenly at the beginning of the Tertiary and which must have been undergoing an important deployment during upper Cretaceous time. The Mongolian Cretaceous insectivores are thus actual representatives so long

hoped for but so little expected of a group hitherto hypothetical and known only by its presumed descendants.

- the Cainozoic mammalian fauna was found to be made up of three categories:

- animals originating in Asia and never found elsewhere
- animals originating in Asia and found subsequently in other regions of the globe such as Europe and America.
- animals originating in America and having migrated to Asia.

According to Osborn quoted in Andrews (1932, p.609):

> These discoveries have established Mongolia as a treasure-house of the life-history of the Earth from the close of the Jurassic time onward to the close of the Pleistocene time, *revealing especially the hitherto unknown high continental life of Cretaceous and Tertiary time.* Consequently, the outstanding discovery of the Expedition is, first, that Gobia since Jurassic time has been a central Asiatic continent extremely favourable to the evolution of reptiles, mammals, insects and plants hitherto known only to the Cretaceous shore-lines of Europe and the Cretaceous sea-borders of the center of America.
>
> ......
>
> In brief, these discoveries establish Mongolia as a chief center of northern terrestrial life-history from the close of the Jurassic time onwards to the very close of Pleistocene time.

In their joint statement on "Unsolved problems in vertebrate palaeontology" (Andrews, 1932, p. 590), Osborn and Granger highlight the remaining gaps in the fossil record of the Gobi Desert at the close of the Mesozoic and the early parts of the Tertiary Period, and the almost complete absence of fossil Equidae: this is all the more surprising in view of their abundance in the fossil record of northern China. Another glaring absence is that of Hominid remains; archaeological traces of human habitation were found, however, showing that the Gobi Desert was once a more habitable environment than at present.

One important legacy of the Central Asiatic Expeditions is the ongoing interest in the region. Numerous expeditions followed:

- the three Soviet-Mongolian expeditions led by Orlov and Efremov in the late 1940's,
- the Sino-Soviet expeditions to Inner Mongolia (1959 and 1960) led by Rozhdestvensky and Zhou,

- the Polish-Mongolian campaigns of the 1960's (led by Zofia Kielan-Jaworowska (Poland) and Dashzeveg & Barsbold (Mongolia)),
- the Sino-Canadian Expedition of the late 1980's: the Dinosaur Project, a collaborative project of the Tyrrell Museum of Palaeontology and the Institute of Vertebrate Palaeontology and Palaeoanthropology,
- a return of the American Museum of Natural History invited by the Mongolian Academy of Sciences in 1990 (Novacek, 1996).

An annotated bibliography of the fossil vertebrate record of the Cretaceous of China and Mongolia alone lists 606 items reflecting the participation of these different national groups in the region; 58 of those result from the Central Asiatic Expeditions, which can be credited with opening this new palaeontological region to science (Klassen & Ryan, 1988).

3.5 – DAVIDSON BLACK, THE PEKING UNION MEDICAL COLLEGE AND PEKING MAN

3.5.1 – The Peking Union Medical College: A Rockefeller project

In 1908, John D. Rockefeller Jr, the Chairman of the Rockefeller Foundation and the son of John D. Rockefeller Sr, of Standard Oil fame, financed an Oriental Education Commission to investigate the state of public health and medicine in China. This mirrored a similar concern within the U.S., following the Flexner Report, which castigated the very uneven quality of medical teaching institutions in the United States. The Rockefeller Foundation funded the reforms proposed in this report. These reforms, known as the Flexner reforms, included closing down the worst medical teaching institutions and financially helping the better ones to attain the standards of the Johns Hopkins Medical School (Hood, 1964; Bullock, 1980).

As a result of the investigation into Chinese medicine, the Johns Hopkins Medical School became a model for China as well, and a medical college was established in China with the aim of providing education to a number of Chinese doctors, whose training in Western medicine up to that date was restricted to missionary schools of unequal standards and conditions. The hope was for a trickle-down effect and the ultimate aim to have a Chinese faculty and board of directors.

The buildings of the London Missionary Society were purchased and renovated in traditional Chinese style in order to include a medical school, a hospital and a nursing school. Teaching started in 1919, even though the official inauguration only took place in 1921, and continued until the beginnings of the 1930's when fears of a Japanese invasion became very real and life at the college destabilised. Xenophobic feeling started to surface in the Chinese community, and most of the foreign staff was expelled in due course.

In December 1941, the College fell into the hands of the Japanese and some of the remaining staff were imprisoned. Teaching eventually stopped, and none of the Chinese staff were allowed to work while the whole college was taken over by soldiers. At the end of the war in 1945, the College was returned to its rightful owners, and funds poured in for the rehabilitation of the College. Work resumed on a small scale, but early in 1949, the People's Republic was proclaimed and, in 1950, all U.S. funds were frozen. At present, the Peking Union Medical College buildings house the Capital Hospital.

The amount contributed to this project by the Rockefeller Foundation was $45,000,000, the largest grant for a single project outside the U.S. made by the Foundation.

3.5.2 – Davidson Black and Peking Man

The appointment in 1919 of Davidson Black (see Box 3.2 and Fig. 3.11) to the Chair of Neurology and Embryology at the Peking Union Medical College came as a unique opportunity to develop his interest in Osborn's and Matthew's theories about Asia as a centre of dispersal for mammals (Osborn, 1910; Matthew, 1915). D. Black graduated from the School of Medicine in Toronto in 1909 with a strong interest in anatomy. His first appointment was at Western University, Cleveland, Ohio and his brief, there, was to develop a museum of comparative anthropology and anatomy. He built on this expertise and further studied anthropology under Grafton Elliot Smith in London and neuroanatomy with Ariens Kappers in Amsterdam (at the Central Institute for Brain Research).

He had also developed some knowledge of and practical experience in geology by working for the Geological Survey of Canada during his holidays.

Soon after his arrival in China, Davidson Black started accumulating comparative osteological material, setting up the laboratory and organising lectures for his students. He soon concentrated on his anthropological interests and left the embryology to his colleague E.V. Cowdry. In 1921, he was appointed the Head of the Anatomy Department (after Cowdry's resignation) and established a close working relationship with John Gunnar Andersson whom he accompanied on archaeological expeditions. In spite of some concerns on the part of the College's Director, Dr Henry S. Houghton, Black was able to carry on and develop his own research and, gradually, he established relationships with the growing group of scientists in Peking: besides John Gunnar Andersson, he started to associate with Amadeus Grabau, Pierre Teilhard de Chardin and Roy Chapman Andrews. He became a close friend of Dr George B. Barbour, an American geologist and palaeontologist from Yenching University and, most importantly in view of later developments, was able to become a trusted friend of Dr Wong Wen-hao and Dr V.K. Ting. Wong Wen-hao had taken over the Directorship of the Geological Survey of China from Ting, who had been instrumental in setting it up. Ting, meanwhile, started to pursue a career in business and politics. Both men were particularly impressed by Davidson Black's personal qualities and his ability to interact with Chinese scientists on equal footing. According to Ting (in Sigmon & Cybulski, 1981, p. 26):

> It is frankly admitted that sometimes we find cooperation between Chinese and foreigners in scientific work rather difficult. The reasons I think are not difficult to seek. Firstly, many foreigners are suffering from a superiority complex. Subconsciously they think somewhat like this; here is a Chinese, he knows something about science, but he is a Chinese nevertheless – he is different from an European, therefore we cannot treat him in the same way. At best his manners become patronizing. On the other hand, their Chinese colleagues are suffering from an inferiority complex. They become self-conscious and supersensitive, always imagining that the foreigner is laughing at them or despising them. Ninety per cent of the trouble between Chinese and foreign colleagues working together comes from these two factors. In my dealing with Davidson Black, and I think Black's colleagues will bear me out, I never found him suffering from such a complex, and his Chinese colleagues became free from theirs. In

politics Black was a conservative, but in his dealings with his Chinese colleagues, he forgot altogether about their nationality or race, because he realized that science was above such artificial and accidental things. This is I think an example for us to follow.

This characteristic empathy with his Chinese colleagues was shared at least with another western scientist working in China at the same time, P. Teilhard de Chardin; both men were singled out in Jia Lanpo's account of the Zhoukoudian project in which he participated from the beginning (Jia & Huang, 1990) and were the subject of very warm appreciations in his book. Davidson Black was dubbed: "The man who forgot his nationality".

On 22 October 1926, most of these scientists, as well as Swedish officials, H.S. Houghton (the Director of P.U.M.C.) and other eminent scholars (Chinese and foreign), were invited to a meeting with the Crown Prince of Sweden (later King Gustavus VI of Sweden) in the Department of Anatomy at the Peking Union Medical College. The Prince was the Chairman of the Swedish China Research Committee, which had funded most of the Swedish projects in China then in progress, including Andersson's work; the Prince was also a keen amateur archaeologist, interested in things oriental and a promoter of archaeological research (Almgren *et al.,* 1932). At the meeting, scientific papers were read including one by Liang Qichao on the current state of archaeology in China, a report by Teilhard de Chardin on his work with Licent in the Ordos, and a survey, by Andersson (on behalf of C. Wiman), of the work that had been carried out at the university of Uppsala on the fossil vertebrate material that he had collected in China. The highlight of the meeting, though, was the description of two human teeth found at Zhoukoudian, based on the photographs and a written description by Otto Zdansky. Zdansky, who had returned to Sweden, had immediately recognised the nature of one of these teeth, an upper molar while the other, a lower premolar, was found on his return to Sweden while he was unpacking the material he had collected (Mateer & Lucas, 1985). This important discovery was published by Zdansky (1927) in the <u>Bulletin of the Geological Society of China</u> and Black (1926), in both <u>Nature</u> and <u>Science</u>. Black's paper, in which he hails the discovery as a confirmation of the hypothesis put forward in an earlier paper (Black, 1925) that "the great center of dispersal of prosimians, lower catarrhines, anthropoid apes and man must have been located in Asia" (Black, 1925, p. 159), generated much interest and scepticism around the world.

On the strength of these finds, Andersson and Black applied successfully for funds to finance a joint Chinese/Swedish/American expedition to Chinese Turkestan. Black also applied to the Rockefeller Foundation for funds to finance a systematic two-year research program at Zhoukoudian. Both applications were granted, but the expedition project had to be abandoned because of Sven Hedin's successful bid for funds to finance his own exploration of Chinese Turkestan (the Sino-Swedish Expedition; see Para. 3.2). Black also applied for funds to finance the establishment of an Institute for the Study of Human Biology, which was to become the Cenozoic Research Laboratory. Davidson Black was appointed as its Head and died at his desk, shortly after (in 1934), from a heart attack. Davidson Black's scientific contributions range beyond his association with the description of Peking Man. He published a total of 51 scientific papers: 24 on the subject of *Sinanthropus pekinensis*) and the remainder, in the fields of anatomy & neuroanatomy, anthropometry and physical anthropology (Cybulski & Gallina, *in* Sigmon & Cybulski, 1981).

3.6 – THE ZHOUKOUDIAN PROJECT AND THE CENOZOIC RESEARCH LABORATORY: A COLLABORATION BETWEEN THE PEKING UNION MEDICAL COLLEGE & THE GEOLOGICAL SURVEY OF CHINA

As a result of Black's successful grant application, a cooperative venture for the systematic study of the Zhoukoudian site was set up. The project was jointly funded by the Rockefeller Foundation ($24,000) and the Geological Survey of China ($4,000). Davidson Black was put in charge of the project. According to Jia & Huang (1990), all specimens collected belonged to the Geological Survey of China, except for the anthropoid material, which remained stored in the Department of Anatomy at the Peking Union Medical College. All research results were to be published in Paleontologia Sinica or in other publications of the Geological Survey of China.

At Zhoukoudian, field work started in 1927 with Anders Birger Bohlin (a Swedish palaeontologist), Li Jie (a Geological Survey of China geologist), Liu Delin (a laboratory technician who had been trained in one of the American Museum of Natural History Central Asiatic Expeditions with W. Granger) and Xie Renfu (an assistant to D. Black) (Jia & Huang, *ibid.*).

During this first field season, 500 crates of fossils were dug up including one human tooth, found by Bohlin, close to where Zdansky had found his. On the basis of this tooth, Black established a new hominid genus and species: *Sinanthropus pekinensis* Black & Zdansky (which was dubbed 'Peking Man' by Grabau). In the 1950's, this taxon was grouped with Java Man (*Pithecanthropus erectus*), and integrated into *Homo erectus* by Le Gros Clark and others after an original suggestion by Mayr (Klein, 1989). Peking Man is now known as *Homo erectus pekinensis.*

The 1928 field season was important on two fronts. Black travelled to Europe and the U.S. where he negotiated, with the Rockefeller Foundation, the terms of the Cenozoic Research Program and additional funds for the Zhoukoudian project. He also consulted with European and American scholars (W.K. Gregory, A. Keith and G. Elliot Smith) about the establishment of his new taxon, *Sinanthropus pekinensis.* In Zhoukoudian, Liu Delin (who had joined the Sino-Swedish Expedition) and Birger Bohlin (who took part in the 1930 season of the Central Asiatic Expeditions) were replaced by two Chinese scientists Yang Zhongjian (C.C. Young) and Pei Wenzhong. Yang Zhongjian had graduated from Peking University in 1923 and completed his Ph.D. in Munich under F. Brolli and M. Schlosser. Yang's doctoral thesis on the fossil rodents of North China was published in Paleontologia Sinica and was the first scientific paper on vertebrate palaeontology published by a Chinese scientist (Young, 1927). Pei Wenzhong had just graduated from Peking University. The 1928 season was shortened by two months because of the war but it nevertheless was very fruitful, producing a large number of mammalian fossils as well as two human lower jaws, confirmation and support for the new genus established by D. Black.

The year 1929 was even more important. A complete Peking Man skullcap was discovered by Pei Wenzhong at the end of the field season and the Cenozoic Research Laboratory was founded. The aims of the Laboratory were two-fold:

1) To address the many geological, palaeontological and geomorphological questions raised by the Zhoukoudian program and to assess the palaeoenvironment and evolution of mammals including primates and hominids.
2) To extend and implement a three-year further excavation program at Zhoukoudian.

These aims and the conditions of operation of the Cenozoic Research Laboratory are laid out in its Constitution (see App. 3.3). Among the specialists allowed for in the Constitution were Teilhard de Chardin and F. Weidenreich. Teilhard de Chardin became the Head of the Zhoukoudian project when Black died in 1934, and Franz Weidenreich took over as the Head of the Cenozoic Research Laboratory until 1941.

Excavations at Zhoukoudian continued until 1936, by which time a large quantity of human remains representing around 40 individuals had been found (Rukang & Shenglong *in* Rukang & Olsen, 1985). The presence of stone artifacts and burnt bones associated with the Peking Man site (Locality 1) demonstrated "the presence of tool- and fire-using hominids in North China in Middle Pleistocene times, a realisation that had major effects on the palaeoanthropological theories of the day" (Rukang & Shenglong, *ibid.*). As a result of improvement in excavation techniques, the Zhoukoudian site was extended and eventually comprised over 20 localities including the Upper Cave which contained remains of Upper Pleistocene *Homo sapiens sapiens*.
Work at Zhoukoudian was resumed after Liberation in 1949 and new skull fragments were found in 1966. Work is still continuing at the Zhoukoudian site, under the auspices of the Institute for Palaeontology and Palaeanthropology (Academia Sinica), with special emphasis on dating and palaeoenvironment reconstruction. The importance and significance of the Zhoukoudian site goes beyond the human remains: the abundant associated vertebrate fauna (more than 100 species at various levels spanning 10 million years, from the Pliocene to the Holocene) has given rise to very detailed studies of environmental changes in the region as well as the interaction between hominids and this

changing environment (Jia & Huang, 1990; Binford & Ho, 1985; Binford & Stone, 1986).

By the 1930's, as a result of the multinational interest in and exploration of the vertebrate fossil record of China, a new set of institutions were developed, specifically dedicated to the study of vertebrate palaeontology and palaeoanthropology. The Cenozoic Research Laboratory, set up to coordinate research on the Peking Man site, was to become the institutional training ground for Chinese vertebrate palaeontologists and act as a focus of interaction between the international palaeontological community, the Geological Survey of China and the Department of Geology at Peking University. Scientific journals were created to publish the results of on-going research, and specific provisions were made to regulate the fate of palaeontological and palaeoanthropological specimens. However, the political circumstances curtailed progress. At the end of the 1930's, the Cenozoic Research Laboratory along with the Geological Survey and the Chinese Government took refuge in Chongqing, in southern China. Wartime palaeontological research and field work became concentrated in central and south-western China, while contacts with foreign palaeontologists on Chinese soil became minimal, with the outstanding exceptions of A. Grabau and P. Teilhard de Chardin.

The human remains that had been found to date in Zhoukoudian were lost in 1941. According to Jia and Huang (1990), when Weidenreich was about to return to the U.S. in April because of the Japanese occupation, it was suggested that he take the fossils with him: but he declined, fearing that they would be confiscated by custom officials; however, he took with him a complete set of casts, photographs, drawings and data while the originals remained in a safe at the Cenozoic Research Laboratory. Wong, fearing for their safety, had the fossils packed up and taken to the U.S. Embassy for safekeeping and later, in August, requested the American Ambassador that they be shipped to the United States. The fossils left Peking early in December for Tianjin with a U.S. marine contingent bound to sail for the United States on *SS President Harrison.* However, at that point, war was declared between the U.S. and Japan (after the Japanese attack on Pearl Harbour, 7 December 1941). The *President Harrison* ran aground, trying to evade a Japanese war ship and never docked. The marines were held prisoners and the Zhoukoudian fossils disappeared. The story of the disappearance of the fossils and of the subsequent post-war search has occupied many minds and led to many hypotheses (Shapiro, 1974; Janus & Brashler, 1975; Van Osterzee, 1999; and others).

3.7 – C.C. YOUNG (YANG ZHONGJIAN) AND THE TRANSITION TO THE INSTITUTE OF VERTEBRATE PALAEONTOLOGY AND PALAEOANTHROPOLOGY (I.V.P.P.)

3.7.1 – C.C. Young (Yang Zhongjian), the 'founder of Chinese Palaeontology'

C.C. Young (1897 – 1979) is hailed as the founder of vertebrate palaeontology by Chinese scientists (Sun & Zhou *in* Wang, Yang &Yang, 1991), and his long career is characterised by his ability to collaborate with a large number of scientists, Chinese and foreign. Indeed, his name has already appeared several times in this account, in relation to Teilhard de Chardin (with whom he co-authored around ten scientific papers) (see Para. 3.1), to the Central Asiatic Expeditions (Young participated in the 1930 season as a representative of the Geological Survey of China) and, finally to the Zhoukoudian Project with which he was associated from the beginning of his career..

According to Yang (1997), it was upon Prof. Grabau's recommendation that C.C. Young, along with two fellow geology graduates from Peking University (Wang Gongmu and Zhang Xizhi), enrolled at the University of Munich. C.C Young did his Ph. D. under Prof. Ferdinand Brolli and Prof. Max Schlosser. His doctoral dissertation completed (Young, 1927), C.C. Young returned to China and joined the Geological Survey and the Zhoukoudian Project as the first qualified Chinese vertebrate palaeontologist. His collaboration with Teilhard de Chardin started with the publication, in 1929, of a report on the Zhoukoudian site (Teilhard de Chardin & Young, 1929) and continued until 1937 when C.C. Young left Peking for Chongqing along with the rest of the Survey. Young and Teilhard de Chardin took part together in the 1930 season of the Central Asiatic Expedition and the Haardt-Citroen Croisière

Jaune (1931 – 1932); they also worked together in Shanxi, Henan and Szechuan.

According to Sun & Zhou (*in* Wang, Yang & Yang, 1991), Young's palaeontological career can be divided into four phases. The first phase (1928 –1934) is dominated by his work on the Zhoukoudian Project and, more generally, with the Cainozoic geology and the mammals of North China, with special emphasis on fossil rodents, lagomorphs and artiodactyls (Teilhard de Chardin & Young, 1931). From 1934 (the second phase), his interests widened and started to include reptiles and the Mesozoic. He described some of the mammal-like reptiles collected by the Sino-Swedish Expedition (Young & Yuan, 1934) and published a series of papers on Late Mesozoic dinosaurs from various localities in Western China. The third phase of his career was initiated in part by the political situation which forced him, along with the Geological Survey and other government institutions, to move to Chongqing (Sichuan). His main scientific work in the region was a collaboration with Bian Meinian on the Triassic reptiles of the Lufeng Basin (Yunnan Province), from which more than 20 scientific papers resulted, some of which appeared in international journals (*e.g.* Young, 1947). This work had international repercussions, and there are numerous quotations in Yang (1997) of letters from palaeontologists with whom Young had developed relations in China or by correspondence: these include Walter Granger and Ralph Chaney (respectively palaeontologist and palaeobotanist in the Central Asiatic Expeditions), Charles Camp, George G. Simpson, Alfred S Romer and others. C.C. Young had the opportunity of meeting these palaeontologists in 1944, during his visit to the United States, as part of a delegation of four Chinese geologists by the Chinese government; during this visit he was based at the American Museum of Natural History, where he had many friends and was able to continue his work on the material from the Lufeng Basin and use the collections of the Museum for comparison. During his stay in the U.S., C.C. Young travelled to many parts of the country, visiting museums and institutions and making new contacts; he returned to China via Europe in 1946. The fourth phase of his career is linked with the transition from the Cenozoic Research Laboratory to the Institute of Vertebrate Paleontology and Paleoanthropology. His palaeontological interests focussed on reptiles, which were the subject of most of his numerous papers until his death, and helped shape China into one of the significant repositories of the fossil record of reptiles.

While in Chongqing, C.C. Young had also been teaching palaeontology and human evolution at the University of Chongqing: one of his students was Minchen Chow (Zhou Minzhen). Zhou was destined to have a dominant role in the post-Liberation history of vertebrate palaeontology of China. Zhou would, in his turn, become the Director of the Institute of Vertebrate Palaeontology and Palaeoanthropology, which C.C. Young was instrumental in creating, as a fully fledged institution within the Chinese Academy of Sciences in 1960.

The scope of C.C. Young's career and contributions, from the first recorded scientific paper on vertebrate palaeontology published by a Chinese scientist (Young, 1927), to his ground-breaking work on Cainozoic mammals and Mesozoic reptiles, and his role in nurturing the Cenozoic Research Laboratory through the political upheavals of the 1940's and transforming it into a vibrant palaeontological institution, today's Institute of Vertebrate Paleontology and Paleoanthropology, truly makes C.C. Young the 'founder' and 'father' of Chinese vertebrate palaeontology. In the course of a palaeontological career spanning 40 years, he published nearly 500 scientific papers and described more than 200 new taxa, mostly fossil mammals and reptiles.

3.7.2 – C.C. Young, Pei Wenzhong, and the birth and development of I.V.P.P.

According to Zhou (1981), the years immediately following the founding of the People's Republic of China were critical in the history of vertebrate palaeontology in China. Work at Zhoukoudian recommenced almost immediately, under the auspices of the newly created Academy of Sciences. C.C. Young himself, along with the psychologist Ting Tsan and the physicist Qian Sanqiang, was instrumental in the establishment of the Chinese Academy of Sciences, under whose auspices the current Institute took form: initially a laboratory of the National Planning and Steering Commission for Geological Works immediately after the founding of the P.R.C. in 1949, it became an integral part of the Chinese Academy of Sciences in 1953, was named the

Institute of Vertebrate Paleontology in 1957 and renamed the Institute of Vertebrate Palaeontology and Paleoanthropology (I.V.P.P.) in 1960. In 1953, the Institute was a small institution with a staff of about 20 under the direction of the palaeontologist Young and the palaeoanthropologist Pei; by 1966 the new Institute had grown to include a staff of 150, 4 research departments, a museum and three well-equipped field stations (including Zhoukoudian), and three serial publications including Vertebrata PalAsiatica, co-founded by C.C. Young and Zhou Minzhen, and the first periodical devoted exclusively to vertebrate palaeontology. The growth of I.V.P.P. was checked by the ten-year long Cultural Revolution (1966 – 1976) but it flourished in subsequent years, under the directorship of Zhou Minzhen, engaging in multiple collaborations with the world palaeontological community. By 1994, it had grown to a much larger organisation with 250 staff (80 scientists supported by technical and administrative staff) headed by a rotating directorship. It includes six departments (Paleoichthyology, Paleoherpetology, Paleomammalogy I (Mesozoic and Early Tertiary) & Paleomammalogy II (Late Tertiary and Quaternary), Paleoanthropology, Palaeolithic Archaeology), the Zhoukoudian International Paleoanthropology Research Centre and a Museum. The Institute currently publishes three periodicals: Vertebrata PalAsiatica, Acta Anthropologica Sinica, and Fossils, a publication aimed at the general public. The monograph series Paleontologia Sinica, started in the 1920's, was joined later by another: Memoirs of the Institute of Vertebrate Paleontology and Paleoanthropology, Academia Sinica.

At its beginnings, the Institute was the only Chinese institution engaged in teaching and research in the field of vertebrate palaeontology and palaeoanthropology. By 1979, vertebrate palaeontology was taught and researched in several universities and technical colleges; four natural history museums, as well as several provincial universities now have departments of vertebrate palaeontology.

The fiftieth anniversary of the seminal discovery of the Peking Man skullcap in 1929 was celebrated in Beijing on December 6-12, 1979. This gathering was attended by a large number of scientists from all corners of China and the number of papers read (109) reflected not only the progress made on the Zhoukoudian site but, also, the flowering of vertebrate palaeontology and palaeoanthropology that had taken place in the intervening years in many parts of China. C.C. Young had passed away at the beginning of that year, but the meeting was attended by Pei Wenzhong, the discoverer of the skullcap. In his address to the meeting, Jia Lanpo, who had been involved with the site since the beginning, summarised the importance of the discovery of Peking Man and its impact on the development of vertebrate palaeontology and palaeoanthropology in China:

> December 2, 1929 was a memorable day in the history of paleoanthropology. The complete skullcap and artifacts of Peking Man and evidence of his use of fire, discovered by Professor Pei Wenzhong, had like a spring thunderbolt awakened those who were shackled by traditional bias and compelled them to admit that in the dawn of the history of man, there had been a stage of *Homo erectus* bearing features of its own in morphology, cultural characteristics, and social set-up. Every piece of fossil occurring at the Peking Man site convinced people of the existence of *Homo erectus*, and an increasing number of people believed that he was the descendant of Australopithecinae, or southern ape, and the precursor of *Homo sapiens*, which emerged after him. The fossils, implements, and evidence of the use of fire found at the Peking Man site have enabled us to have a better understanding of man's past, thus providing an important missing link in evolution...
>
> The Zhoukoudian project has trained at least two generations of specialists in paleoanthropology, paleolith archaeology, and vertebrate paleontology. The project in its early days was under the direction of the Cenozoic Research Laboratory of the Geological Survey of China, which was the predecessor of the Institute of Vertebrate Paleontology and Paleoanthropology of the Chinese Academy of Sciences. It is said that Yang Zhongjian and Pei Wenzhong were the men who laid the cornerstone of these branches of science in China. I deem this to be an apt evaluation of the two scholars, borne out by history itself. Recent discoveries of human fossil remains and paleoliths across the country have been made possible by the Zhoukoudian Project, with its training of specialists and provision of facilities.
>
> ...
>
> There have been many Chinese and foreign scholars of the older generation who have contributed directly to the Zhoukoudian project. These include the geologist Li Jie of China, paleontologist Yang Zhongjian, anthropologist Davidson Black of Canada, geologist Johan Gunnar Andersson of Sweden, paleontologist Birger Bohlin of Sweden, paleontologist Otto Zdansky of Austria, anthropologist Franz Weidenreich of the United States, and paleontologist Teilhard de Chardin of France. Many of them

have passed away, but our memory and veneration of them shall never fade. (Jia & Huang, p. 229.)

This is a fitting tribute, indeed, to the contributions to and impact of those scientists directly involved with the Zhoukoudian project. More indirect, but no less important, were the roles played by the Central Asiatic Expeditions of the American Museum of Natural History and the Sino-Swedish Expedition, not only in furthering the geological and palaeontological understanding of the region but, also, in interacting with and providing training to the rising generation of Chinese vertebrate palaeontologists.

CONCLUSION: THE LEGACY

Impact of discoveries on palaeontological thinking

The significance of the impact of the palaeontological discoveries made during the period under study can be measured from the extensive review of the Chinese fossil vertebrate record in Lucas (2001). In the context of the importance of Asia for the evolution of vertebrates, especially mammals (Beard, 1998, in Beard & Dawson, 1998), this impact is even greater. A survey of the bibliography at the end of Lucas (*ibid.*) shows that out of a total of 807 references, 80 were written prior to 1950, by workers whose names have figured prominently in this study (J.G. Andersson, R.C. Andrews, Bian Meinian, D. Black, B. Bohlin, A.W. Grabau, W. Granger, J.S. Lee, W.D. Matthew, H.F. Osborn, Pei Wenzhong, P. Teilhard de Chardin, F. Weidenreich, C. Wiman, C.C. Young and Otto Zdansky), or workers studying the specimens collected by the expeditions that have contributed to the exploration of the Central Asiatic fossil record in the first half of the twentieth century (J.J. Burke, C.L. Camp, E.H. Colbert, C.W. Gilmore, C.C. Mook, F.K. Morris). Their contribution is especially important in the following areas: Mesozoic palaeoherpetology, Cainozoic palaeomammalogy and Quaternary palaeoanthropology. The post-1950's references come from three sources:

- the founding members of the Chinese palaeontological community,
- the new generation of Chinese vertebrate palaeontologists

- international participants in collaborative projects with Chinese palaeontologists.

Development of a palaeontological community in China

By the 1930's, as a result of the multinational interest in and exploration of the vertebrate fossil record of China and Central Asia, a new set of institutions were developed, specifically dedicated to the study of vertebrate palaeontology. The Cenozoic Research Laboratory, set up to coordinate research on the Peking Man site was to become the institutional training ground for Chinese vertebrate palaeontologists and act as a focus of interaction between the international palaeontological community, the Geological Survey of China and the Department of Geology at Peking University. Scientific journals were created to publish the results of on-going research and specific provisions were made to regulate the fate of palaeontological and palaeoanthropological specimens. However, the political circumstances were to curtail progress. At the end of the 1930's, the Cenozoic Research Laboratory along with the Geological Survey and the Chinese Government took refuge in Chongqing, in south central China. Wartime palaeontological research and field work became concentrated in central and south-western China, while contacts with foreign palaeontologists on Chinese soil became minimal, with the outstanding exceptions of A. Grabau and P. Teilhard de Chardin.

Summary

As a result of this multinational effort to explore and document the central Asiatic fossil record, a range of objectives were achieved:

1. Knowledge of the fossil vertebrate record of the region considerably increased. Whereas in 1915, the oldest known fossil vertebrates were Late Tertiary in age, by the 1930's, the known fossil record had been extended back into the Permian. Furthermore, the geological setting and palaeogeographical implications of the central Asiatic fossil record had been documented.

2. Osborn's and Matthew's hypothesis about the importance of the region for mammalian evolution was substantiated. The discoveries of the Central Asiatic Expeditions and the Sino-Swedish Expeditions also showed that the central Asiatic region was a major theatre of reptilian evolution (namely, dinosaurs and mammal-like reptiles).

3. The discovery of the Peking Man site in Zhoukoudian occurred as a result of the interaction between the foreign scientists at work in the region and local knowledge of the source of "dragon bones", which had formed the primary material on which the first review of the mammalian fossil record of the region had been based (Schlosser, 1903). In response to the need for the systematic study of this important site, cooperative agreements were signed between the Geological Survey of China and the Rockefeller Foundation in 1926 leading to the foundation of the Cenozoic Research Laboratory.

4. Other agreements had been signed just previously between the Geological Survey of China and the Swedish government leading to the production of Paleontologica Sinica, and a set of guidelines regarding the conservation of specimens. These agreements were critical in the development of a Chinese vertebrate palaeontological community as they provided a conduit through which funds were made available for the training of Chinese palaeontologists and the publication of their work.

REFERENCES

ALMGREN, O. *et al.*, 1932. Crown Prince Gustaf Adolf as a promoter of archaeological research. *Bulletin of the Museum of Far Eastern Antiquities (Stockholm)* 4, pp. 1-14.

ANDERSSON, J.G., 1934: *Children of the Yellow Earth.* Kegan Paul, Trench, Trubner & Co. Ltd, London.

ANDREWS, R.C., 1929. *Ends of the Earth.* Putnam's Sons, New York.

ANDREWS, R.C., 1932. *The New Conquest of Central Asia – A Narrative of the Explorations of the Central Asiatic Expeditions in Mongolia and China, 1921 – 1930.* The American Museum of Natural History, New York.

BARBOUR, G.B., LICENT, E. & TEILHARD DE CHARDIN, P., 1926. Geological Study of the Deposits of the Sangkanho Basin. *Bull. Geol. Soc. China*, Vol. V, pp. 263-278.

BEARD, K.C. & DAWSON, M.R., 1998. The dawn of the age of mammals in Asia. *Bulletin of Carnegie Museum of Natural History* 34.

BERGMAN, F., BEXELL, G., BOHLIN, B. & MONTELL, G., 1945. History of the Expedition in Asia 1927 – 1935. Part IV: General Reports of Travels and Field-Work. *Reports from the Scientific Expedition to the North-Western Provinces of China under the Leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 26.

BINFORD, L.R. & HO, C.K., 1985. Taphonomy at a distance: Zhoukoudian, "The Cave Home of Beijing Man"? *Current Anthropology* 26(4), pp. 413-442.

BINFORD, L.R. & STONE, N.M., 1986. Zhoukoudian: A closer look. *Current Anthropology* 27(5), pp. 453-475.

BLACK, D., 1925. Asia and the dispersal of the primates. *Bulletin of the Geological Society of China* 4, pp. 133 – 183.

BLACK, D., 1926. Tertiary Man in China: The Chou Kou Tien discovery. *Nature* 118, pp. 733-734.

BLACK, D., 1926. Tertiary Man in China: The Chou Kou Tien discovery. *Science* 64, pp. 586-587

BLACK, D., TEILHARD DE CHARDIN, P., YOUNG, C.C. & PEI, W.C., 1933. Fossil Man in China. *Mem. Geol. Surv. China,* Ser. A, No11.

BOHLIN, B., 1942. The fossil mammals from the Tertiary deposits of Taben-buluk, western Kansu – Insectivora and Lagomorpha. *Reports from the Scientific Expedition to the north-western Provinces of China under the leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 20.

BOHLIN, B., 1946. The fossil mammals from the Tertiary deposits of Taben-buluk, western Kansu –Simplicidentata, Carnivora, Artiodactyla, Perissodactyla and Primates. *Reports from the Scientific Expedition to the north-western Provinces of China under the leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 28.

BOULE, M., BREUIL, H., LICENT, E. & TEILHARD DE CHARDIN, P., 1928. Le Paléolithique de la Chine. *Arch. de l'Inst. de Pal. Hum.,* Mem.4, Paris.

BULLOCK, M.B. (1980): An American Transplant - The Rockefeller Foundation and Peking Union Medical College. University of California Press.

CUENOT, C., 1958. *Pierre Teilhard de Chardin - Les Grandes Etapes de son Evolution.* Librairie Plon, Paris.

CUENOT, C., 1963. *Teilhard de Chardin.* Coll. Ecrivains de Toujours, Editions du Seuil.

GRABAU, A.W., 1931. *The Permian of Mongolia – A report on the Permian fauna of the Jisu Honguer Limestone of Mongolia and its relation to the Permian of other parts of the world. In* Reeds, C.E., Ed., *Natural History of Central Asia,* Vol.VI, The American Museum of Natural History, New York.

HEDIN, S., 1900. *Die geographisch-wissenschaftlichen Ergebnisse meiner Reisen in Zentralasien 1894-1897.* Dr A. Petermanns Mitteilungen, Ergänzungsheft Nr.131, Gotha.

HEDIN, S., 1904-1907. *Scientific Results of a Journey in Central Asia, 1899-1902.* Stockholm.

HEDIN, S., 1918-1927. *Eine Routenaufnahme durch Ostpersien, I-II.* Stockholm.

HEDIN, S., 1917-1922. *Southern Tibet. Discoveries in Former Times Compared with my own Researches in 1906-1908.* Vols 1-9, Atlas, Maps 1-2. Stockholm.

HEDIN, S., 1991. *My Life as an Explorer.*Oxford University Press.

HEDIN, S. & BERGMAN, F., 1943a. History of the Expedition in Asia 1927 – 1935. Part I: 1927-1928. *Reports from the Scientific Expedition to the North-Western Provinces of China under the Leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 23.

HEDIN, S. & BERGMAN, F., 1943b. History of the Expedition in Asia 1927 – 1935. Part II: 1928-1933. *Reports from the Scientific Expedition to the North-Western Provinces of China under the Leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 24.

HEDIN, S. & BERGMAN, F., 1944. History of the Expedition in Asia 1927 – 1935. Part III: 1933-1935. *Reports from the Scientific Expedition to the North-Western Provinces of China under the Leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 25.

HOOD, D. (1964): *Davidson Black - A biography.* University of Toronto Press.

JANUS, C.G. & BRASHLER, W., 1975. *The search for Peking Man.* Macmillan, New York.

JIA, L. & HUANG, W., 1990. *The story of Peking Man – From archaeology to mystery.* Foreign Languages Press, Beijing and Oxford University Press, Hong Kong.

KARLGREN, B., 1961. Johan Gunnar Andersson – In memoriam. *Bulletin of Museum of Far Eastern Antiquities* 33, pp. v – ix.

KISH, G., 1988. *Tibet au Coeur – La Vie de Sven Hedin.* Editions R. Chabaud – Peuples du Monde.

KLASSEN, M. & RYAN, M., 1988. *Annotated Bibliography of Fossil Vertebrates – The Upper Cretaceous of China and Mongolia.* Occasional Paper of the Tyrrell Museum of Palaeontology #5, Drumheller, Alberta.

KLEIN, R.G., 1989. *The human career.* The University of Chicago Press.

LEROY, P., 1971. *Dans le sillage des Sinanthropes – Lettres Inédites de Pierre Teilhard de Chardin et Johan Gunnar Andersson 1926 – 1934.* Fayard

LICENT, E. & TEILHARD DE CHARDIN, P., 1925. Le Paléolithique de la Chine. *L'Anthropologie,* t. XXXV, pp. 201-234.

LICENT, E., TEILHARD DE CHARDIN, P. & BLACK, D., 1926. On a Presumably Pleistocene Human Tooth from the Sjara-Osso-Gol (South-Eastern Ordos) Deposits. *Bull. Geol. Soc. China,* Vol. V, pp. 285-290.

LINNÉ, S., 1965. Sven Hedin and the Ethnographical Museum of Sweden, Stockholm. *Ethnos* 30, pp. 25-38.

LUCAS, S.G., 2001. *Chinese Fossil Vertebrates.* Columbia University Press, New York.

MATEER, N.J. & LUCAS, S.G., 1985. Swedish vertebrate palaeontology in China: A history of the Lagrelius Collection. *In* S.G. Lucas and N.J. Mateer (eds). *Bulletin of the Geological Institutions of the University of Uppsala*, N.S., Vol. 11, pp. 1-24.

MATTHEW, W.D., 1915. Climate and Evolution. *Annals of the New York Academy of Sciences XXIV*, pp. 171-318.

MONTELL, G., 1965. Sven Hedin – The Explorer. *Ethos* 30, pp. 7-24.

NOVACEK, M., 1996. *Dinosaurs of the Flaming Cliffs*. Anchor Books, Doubleday, New York.

OSBORN, H.F.,1910. *The Age of Mammals in Europe, Asia and North America*. The Macmillan Company, New York.

OSBORN, H.F., 1930. To the benefactors Central Asiatic Expeditions. *In* Matthew, Granger *et al.*, *Preliminary Contributions in Geology, Palaeontology, Archaeology, Botany and Zoology, 1926 – 1929.* American Museum of Natural History, p.3.

RAINGER, R., 1991. *An agenda for antiquity – Henry Fairfield Osborn and Vertebrate Paleontology at the American Museum of Natural History, 1890 – 1935.* The University of Alabama Press, Tuscaloosa and London.

RUKANG, W. & OLSEN, J.W., 1985. *Palaeoanthropology and Palaeolithic Archaeology in the People's Republic of China*. Academic Press, Inc.

SCHLOSSER, M., 1903. Die fossilen Saugethiere Chinas nebst einer Odontographie der recenten Antilopen. *Abhandlungen bayer Akademie der Wissenschaften* 22, pp 1-221.

SCHMITZ-MOORMANN, N. & K.,1971. *Pierre Teilhard de Chardin - L'Oeuvre Scientifique.* Walter-Verlag Olten und Freiburg im Breisgau, 10 volumes.

SCHÖBEL, J., 1985. Published papers by Johan Gunnar Andersson, Birger Bohlin, Carl Wiman and Otto Zdansky on the archaeology, geology and palaeontology of China and Mongolia. *In* S.G. Lucas and N.J. Mateer (eds).*Bulletin of the Geological Institutions of the University of Uppsala*, N.S., Vol. 11, pp. 25-30.

SHAPIRO, H.L., 1974, *Peking Man.* Simon & Schuster, New York.

SIGMOND, B.A. & CYBULSKI, J.S., 1981. *Homo erectus – Papers in Honor of Davidson Black.* University of Toronto Press.

SIMPSON, G.G., 1928. Affinities of the Mongolian Cretaceous Insectivores. *American Museum Novitates No 330*, pp. 1-11.

SUN, A. & ZHOU, M., 1991. Professor Yang Zhong-jian – Founder of Chinese vertebrate palaeontology. *In* WANG, H.Z., YANG, G.R. & YANG, J.Y. (Eds). *Interchange of Geoscience Ideas between the East and the West.* Proceedings of the XVth International Symposium of INHIGEO October 25-31, 1990, Beijing.

TEILHARD DE CHARDIN, P., 1922. Sur une faune de mammifères pontiens provenant de la Chine septentrionale. *C.R. somm. Soc. Géol. France*, séance du 9 juin 1922, t. XXII, pp. 129-131.

TEILHARD DE CHARDIN, P., 1925. Le Massif Volcanique du Dalai-Noor (Gobi Oriental). *Bull. Volcanologique*, Naples, nos 3-4, 1er et 2e trim., pp. 100-108.

TEILHARD DE CHARDIN, P., 1926a. Description de Mammifères Tertiaires de Chine et de Mongolie. *Ann. de Pal.*, t. XV, Paris, pp. 1-52.

TEILHARD DE CHARDIN, P., 1926b. Le Néolithique de la Chine d'après les Découvertes du Dr Andersson. *L'Anthropologie*, t. XXXVI, pp. 117-124.

TEILHARD DE CHARDIN, P., 1928a. La Nature et la Succession des Eruptions Post-Paleozoïques en Chine Septentrionale. *C.R. Acad. Sc.*, t. CLXXXVI, pp. 960-961.

TEILHARD DE CHARDIN, P., 1928b. Observations sur la Lenteur d'Evolution des Faunes de Mammifères Continentales. *Palaeobiologia*, Vienne & Leipzig, Vol.1, pp. 55-60.

TEILHARD DE CHARDIN, P., 1932a. The Geology of the Weichang Area. *Bull. Geol. Survey China*, No 19, pp. 1-49.

TEILHARD DE CHARDIN, P., 1932b. Les Résultats Scientifiques de l'Expédition Centre-Asie. *La Géographie (Terre, Air, Mer)*, Paris, décembre 1932, t. LVIII, pp. 379-390.

TEILHARD DE CHARDIN, P., 1943a. Géobiologie et Geobiologia. *Geobiologia* Vol.I, Pékin.

TEILHARD DE CHARDIN, P., 1943b. The Genesis of the Western Hills of Peking. *Geobiologia* Vol.I, Pékin.

TEILHARD DE CHARDIN, P., 1945a. Un Problème de Geologie Asiatique. Le Faciès Mongol. *Geobiologia* Vol.II, Pékin.

TEILHARD DE CHARDIN, P., 1945b. The Geology of the Western Hills Additional Notes. *Geobiologia* Vol.II, Pékin.

TEILHARD DE CHARDIN, P., 1945c. The Geological Structure of the Shihmenchai Basin, near Shanhaikwan (North Hopei). *Geobiologia* Vol.II, Pékin.

TEILHARD DE CHARDIN, P., BARBOUR, G.B. & BIEN, M.N., 1935. A Geological Reconnaissance across the Eastern Tsinling. *Bull. Geol.Survey China*, No 25, pp. 9-37.

TEILHARD DE CHARDIN, P. & FRITEL, P.-H., 1925. Note sur Quelques Grès Mesozoïques à Plantes de la Chine Septentrionale. *Bull. Soc. Geol. France,* t. XXV, pp. 523-540.

TEILHARD DE CHARDIN, P., LEROY, P., TRASSAERT, M. & ROI, J., 1940. The Institute of Geobiology in Peking. *Bull. Geol. Soc. China,* Vol. XIX(4), pp. 3216-3217.

TEILHARD DE CHARDIN, P. & LICENT, E., 1924. On the Geology of the Northern, Western and Southern Borders of the Ordos, China. *Bull. Geol. Soc. China*, Vol.III, pp. 37-44.

TEILHARD DE CHARDIN, P. & LICENT, E. 1927. Observations sur les Formations Quaternaires et Tertiaires Supérieures du Honan Septentrional et du Chansi Meridional. *Bull. Geol. Soc. China*, vol. VI, pp. 129-148.

TEILHARD DE CHARDIN, P. & PEI, W.C., 1934. New Discoveries in Choukoutien 1933-1934.*Bull. Geol. Soc. China,* Vol. XIII, pp. 369-394.

TEILHARD DE CHARDIN, P. & PIVETEAU, J., 1930. Les Mammifères Fossiles de Nihowan. *Ann. de Pal.,* t. XIX, Paris, pp. 1-134.

TEILHARD DE CHARDIN, P. & TRASSAERT, M., 1937a. The Proboscideans of South-Eastern Shansi. *Pal. Sin.* ser. C, Vol. XIII, fasc.1.

TEILHARD DE CHARDIN, P. & TRASSAERT, M., 1937b. The Pliocene Camellidae, Giraffidae, and Cervidae of South Eastern Shansi. *Pal. Sin.*, new ser. C, No1, whole ser. No102.

TEILHARD DE CHARDIN, P. & TRASSAERT, M., 1938. Cavicornia of South-Eastern Shansi. *Pal. Sin.*, new ser. C No 6, whole ser. No 115.

TEILHARD DE CHARDIN, P. & YANG, K., 1937. The Structural Geology of Eastern Shantung. *The Geological Bulletin* (Bull. Geol. Surv. China) No 29, pp. 85-108.

TEILHARD DE CHARDIN, P. & C.C. YOUNG, 1929. Preliminary Report on the Chou Kou Tien Fossiliferous deposits. *Bull. Geol. Soc. China*, Vol. VIII, pp. 171-202.

TEILHARD DE CHARDIN, P. & C.C. YOUNG, 1930. Preliminary Observations on the Pre-Loessic and Post-Pontian Formations in Western Shansi and Northern Shensi. *Mem. Geol. Surv. China*, Ser. A, No 8.

TEILHARD DE CHARDIN, P. & C.C. YOUNG, 1931. Fossil mammals from the Late Cenozoic of Northern China. *Paleontologia Sinica* Ser. C, X(1), 67 pp.

TEILHARD DE CHARDIN, P. & YOUNG, C.C., 1933. The Late Cenozoic Formations of S.E. Shansi. *Bull. Geol. Soc. China,* Vol. XII, pp. 207-248.

VAN OOSTERZEE, P., 1999. *Dragon bones – The search for Peking Man.* Allen & Unwin, Australia.

WANG, H.Z., YANG, G.R. & YANG, J.Y., Eds, 1991. *Interchange of Geoscience Ideas between the East and the West.* Proceedings of the XVth International Symposium of INHIGEO October 25-31, 1990, Beijing.

YANG, X., 1997. *A brief of the Interchanges between Professor Young Chunchien and American scientists.* Institute of Vertebrate Paeontology and Paeoanthropology, Chinese Academy of Sciences.

YOUNG, C.C., 1927. Fossile Nagetiere aus Nord-China. Paleontologia Sinica, Ser. C 5(3), pp. 1-82

YOUNG, C.C., 1947. Mammal-like reptiles from Lufeng, Yunnan, China. *Proc. Zool. Soc. London* 117 (parts II & III), pp. 537-597.

YOUNG, C.C. & YUAN, P.L., 1934. On the occurrence of *Lystrosaurus* in Sinkiang. Bulletin of the Geological Society of China 8, pp. 575-580

ZHOU, M., 1979. Young, Chung-chien 1897 –1979. *SVP News Bulletin* 116, pp. 66 –69.

ZHOU, M., 1981. Vertebrate paleontology in China, 1949-1979. *Geological Society of America Special Paper* 187, pp. 15 – 20.

ZDANSKY, O., 1927. Preliminary notice on two teeth of a hominid from a cave in Chihli (China). *Bulletin of the Geological Sciences of China* 5(3-4), pp. 1-87.

TABLES

Table 3.1 – Scientific results of the Sino-Swedish Expedition – Publication List

STAFF (FOREIGN)	
Roy Chapman Andrews	Leader and Zoologist
Walter Granger	Palaeontologist
Charles P. Berkey	Geologist
Frederick K. Morris	Topographer
J.B. Shackelford	Cinematographer
S. Bayard Colgate	Transportation Officer
F.A. Larsen	Interpreter
T. Badmajapoff	Mongolian Diplomatic Representative

NATIVE STAFF
3 Chinese taxidermists
3 Chinese cooks
3 Chinese chauffeurs
6 Mongol camel men
3 Mongol camp assistants
2 Mongol soldiers

EQUIPMENT
74 camels
3 Dodge motor cars
2 Fulton one-ton trucks.

Table 3.2 – Staff & Equipment list - Third Asiatic Expedition (Andrews, 1919-1932)

GOBI EXPEDITION OF 1919 - PLANS AND SPECIFICATIONS (*in* Andrews, 1919-1932)

Object: To get to Urga eventually.
Motto: We should worry

PERSONNEL

R.C. Andrews	" Gobi ", head cook, skinner, butcher and general camp arranger.
Mrs Andrews	" Gobina ", photographer, assistant cook, meal and table arrangements.
Mr Mac Callo	" Delco ", chief electrician, tent pegger, water purveyor and wood cutter.
Mrs Mac Callo	" Delcette ", coffee, tea & soup supply, table linen and cutlery.
Mr C.L. Coltman	" Boss ", motor engineer, time keeper, expert and general commander.
Mrs Coltman	" Bossene ", assistant cook, quartermaster, finder of lost articles.
Mr Owen	" Uncle John ", assistant motor engineer.

REGULATIONS

1. No cussing (sic) the weather.
2. No insinuation if there is sand in the soup.
3. No grouching against the gasoline in the drinking water.
4. No profanity unless of the picturesque variety.
5. All hands assist at unpacking and packing in evening and mornings stops and starts.
6. All male members must take share in pumping tires and at work requiring more than hot air.
7. Camps will be made, starts made, stops made, and such disarrangements by vote, 4 votes carrying the day.
8. Any breach of regulations will be considered by court after dinner and during smoking hour (when most lenient treatment can be hoped for) and penalty judged will be walked by the culprit in miles recorded by speedometer at start of following day.
9. If male members of expedition cannot supply fresh meat on any one day, they will not be allowed to smoke after dinner.

PLANS

1. To have a thoroughly good time
2. To get good specimens of all game available
3. Camp early and start late on general principles
4. To stop and investigate, or leave the road and explore whenever desired.

Table 3.3 – Personnel and Regulations – Second Asiatic Expedition (Andrews, 1919-1932)

NAME	QUALIFICATION	TIME
Andrews, R. C.	Zoologist (and leader)	1921 – 1930
Badmajoff, T.	Mongolian political representative	1922
Beckwith, R.H.	Geologist	1926 – 1927
Berkey, C.P.	Geologist (Chief)	1922 – 1925
Butler, F.B.	Topographer (Assistant)	1925
Chaney, R.W.	Palaeobotanist	1925
Colgate, S.B.	Motor Transport	1922
Eriksson, J.	Agent in Mongolia	1926 – 1930
Garber, A.Z.	Surgeon	1930
Grabau, A.W.	Research Associate	1922 – 1930
Granger, W.	Palaeontologist (Chief) and Second-in-Command	1921 – 1930
Hill, W.T.P.	Topographer	1928
Horvath, G	Motor Transport	1928
Johnson, A.F.	Palaeontologist (Assistant)	1923
Johnson, C.V.	Motor Transport	1923
Kaisen, P.C.	Palaeontologist	1923
Larsen, F.A.	Interpreter & Expedition Agent	1922 –1926
Loucks, H.A.	Surgeon	1925
Lovell, N.	Motor Transport	1925
Matthew, W.D.	Palaeontologist	1926
Morris, F.K.	Geologist	1922, 1923, 1925
Nelson, N.C.	Archaeologist	1925
Olsen, G.	Palaeontologist (Assistant)	1923 – 1925
Perez, J.A.	Surgeon	1928
Pond, A.W.	Archaeologist	1928
Pope, C.H.	Herpetologist	1921 – 1926
Roberts, L.B.	Topographer (Chief)	1925
Robinson, H.O.	Topographer	1925
Shakelford, J.B.	Photographer	1922, 1925, 1928
Spock, L.E.	Geologist	1928
Teilhard de Chardin, P.	Geologist	1930
Thomson, A.	Palaeontologist (Assistant)	1928 – 1930
Wyman, W.G.	Topographer	1930
Young, J.M.	Motor Transport (Chief)	1923 - 1930

Table 3.4 – Composite Table of Scientific and Technical Staff in the Central Asiatic Expeditions (Andrews, 1932, p. xi)

APPENDICES

AGREEMENT BETWEEN THE CHINESE MINISTRY OF FOREIGN AFFAIRS AND THE SWEDISH LEGATION.

According to the scheme of your expedition sent by the Swedish Minister and yourselves, a party of Swedish and Chinese scientists including specialists of aviation intend to go to the two provinces, Kansu and Sinkiang, to make archaeological researches. A first expedition using camels and horses intends to leave Peking at the beginning of 1927 and to study along the road the possibility of using aeroplanes for researches in a next (second) expedition. You declared that you were engaged to do no unlawful action and to take all responsibility for any accident that might happen as a consequence of the researches. The Chinese Government in view of encouraging the archaeological investigations approves of the scheme of the first expedition and has already instructed the respective local authorities for protection and help at their discretion. Travelling passport will be issued to you when you have forwarded to the Ministry the names and qualifications of the members of the expedition.

This is to let you know of the above contents and
Wishing you good health

Signed: Wai Chiaopu
Translated: Wong Wenhao
Dated: 1 January 1927

Appendix 3.1: Reproduced from Hedin & Bergman (1943a, p.7)

AGREEMENT BETWEEN THE FEDERATION OF SCIENTIFIC INSTITUTIONS OF CHINA AND DR SVEN HEDIN FOR ORGANIZING A SCIENTIFIC MISSION TO NORTH-WESTERN CHINA

1. The Federation of the Scientific Institutions of China, hereafter named the Federation, organizes with the collaboration of Dr Sven Hedin a scientific mission to North-Western China to be named "The Scientific Mission to North-Western China under the Commission of the Federation of Scientific Institutions of China" hereafter named the Mission.

2. The Federation elects a Board of Directors whose specific function is to supervise and direct the activities of the Mission in accordance with this agreement.

3. The complete staff of the Mission, both Chinese and foreign, is to be appointed by the Board of Directors, including those already selected by Dr Hedin, and approved by the Federation; the names, nationalities, qualifications, and duties are to be clearly tabulated and attached to this agreement.

4. The Board of Directors appoints, out of the staff of the Mission, two Field Directors, one Chinese and one foreign; and Dr Sven Hedin is to be the foreign Field Director.

5. The duties of the Chinese and foreign Field Directors are as follows:-
    (a) The foreign Field Director is empowered to decide the movement of the Mission, the time of work etc., in consultation with the Chinese Field Director.
    (b) As to the distribution of work, the foreign Field Director should confer beforehand with the Chinese Field Director, and should secure the latter's agreement before giving orders. In case the Chinese Field Director proposes any method of distribution of work, he should also secure the agreement of the foreign Field Director.

Appendix 3.2: Reproduced from Hedin & Bergman (1943a, p. 53)

(c) The Chinese Field Director is empowered to undertake any dealings with the local authorities.

(d) The transportation of materials collected is to be entrusted to the Chinese Field Director.

6. The expenditure of the Mission and other necessary equipments are subject to the following regulations:-

   (a) Dr Sven Hedin undertakes to pay all the expenses for the complete staff of its food, tents, coolies, camels, medical attendance and other necessary expenditure throughout the journey viz. starting from the day when the Mission leaves Peking, and ending on the day when it returns to Peking. Dr Hedin is also to undertake to defray the expenditure for transporting to Peking the materials collected.

   (b) Dr Sven Hedin undertakes to pay the salaries of the foreign staff, and further agrees to contribute $850.00 Chinese currency, per month to the Federation beginning from the day when the mission leaves Peking and ending on the day when it returns to Peking. The disposal of this fund is to be definitely stated in a note attached to this agreement.

   (c) Other related matters are to be dealt with as they arise according to the joint decision of the Chinese and Foreign Field Directors, and are to be reported to the Board of Directors.

7. The Mission is to follow the road Peking, Pao-t'ou, Sogho-nor, Hami, Ti-hua, Lop-nor, and Charchan. In case of necessity, the Field Directors of the Mission may effect some slight modification with their joint decision. Important modifications cannot, however, be effected unless they are sanctioned by the Board of Directors.

8. The duration of the Mission is not to exceed two years, counting form the day when it leaves Peking.

Appendix 3.2: Reproduced from Hedin & Bergman (1943a, p. 53) (Continued)

9. The principal subjects to be dealt with by this Mission are as follows: - Geology, Geomagnetism, Meteorology, Astronomy, Ethnology, Archaeology, Ethnography.

10. No work should be undertaken by the Staff which directly or indirectly infringes national sovereignty or endangers national defence. The Chinese Field Director is fully empowered to stop any such undertakings.

11. Maps prepared during the journey should not exceed the scale of 1:300,000 except for the working areas.

12. Under no pretext whatsoever, are the members of the staff of the Mission allowed to inflict any damage upon buildings of historical and artistic value; and no person in the Mission is allowed to purchase, in his private capacity, archaeological material.

13. No archaeological excavation is to be undertaken by the Mission except on such a small scale as to hinder in no serious way the movement of the Mission, and the material thus collected requires no special equipment for transportation; this is to say that archaeological excavations on a large scale can also be undertaken if they do not hinder the movements of the Mission.

14. The materials obtained by the Mission are to be disposed in two ways as stated below:-
    - (a) All archaeological material is to be handed over to the Chinese Field Director or his appointee, and to be delivered to, and deposited with the Federation.
    - (b) All geological specimens are to be treated in the same way as stated above. But a duplicate set will be offered to Dr Sven Hedin after the material has been examined by the Board of Directors.

Appendix 3.2: Reproduced from Hedin & Bergman (1943a, p. 53) (Continued)

15. The records of the field data are to be dealt with in the following ways:-

(a) Photographic plates are to be inspected by the Board of Directors, and a set of prints must be deposited with the Federation.

(b) All graphic records must be examined by the Board of Directors, within six months of delivery.

(c) Field notes, sketches and diaries are also subject to examination within six months of delivery.

(d) Maps are first to be examined, within six months of delivery, by the Board of Directors, who then deliver them to the Headquarters of General Staff for further examination.

(e) Cinematographic records are to be examined by the Board of Directors within six months of delivery and shown to the public in Peking for the first time. A duplicate copy of the cinematographic film is to be deposited with the Federation. No result shall be published which does not satisfy the regulations as stated above.

15. The preliminary report of the scientific result is to be formally published under the name of the Federation in accordance with the following agreements:-

(a) There shall be about 200 pages octavo of report for each science, in both Chinese and English languages.

(b) The Federation shall bear the expenditure in connection with the printing of the preliminary report. One hundred copies of this report shall be presented to Dr Hedin.

(c) Except the names of the two field directors heading the list, the names of the authors are to be alphabetically arranged.

(d) The preliminary report shall be completed within two years and six months after the conclusion of the Mission.

Appendix 3.2: Reproduced from Hedin & Bergman (1943a, p. 53) (Continued)

15. The detailed reports of the Mission are to be published in accordance with the following agreements:

(a) The publication of this series shall take place after the publication of the preliminary report.

(b) The detailed reports are to be divided into two series. Series A shall consist of Geology, Ethnology, Archaeology and Ethnography and Series B, Astronomy, Meteorology, and Terrestrial Magnetism. Series A shall be published in China at the expense of the Federation. Series B shall be published in Europe at the expense of Dr Hedin. One hundred copies of each series are to be exchanged between the two parties, and the rest are left at the discretion of each publishing party.

(c) All the results in connection with Series A, whether obtained by Chinese or European members of the Mission, are to be handed to the Board of Directors. Those with Series B under the same category shall be handed to Dr Hedin within six months from delivery, after being examined by the Board of Directors.

(d) All publications in both Series A and B are to be published under a common title and in the same size and form.

(e) These publications are to be published under the name of the Federation. Besides the name of the author or authors printed on the cover, the names of the two Field Directors shall be printed as Chief Editors, but with the name of the Chinese Field Director in the first place for Series A, and the name of Dr Hedin in the first place for Series B.

15. The four meteorological field stations together with their instruments and equipments which have already been offered by Dr Sven Hedin to China, will be handed over to the Board of Directors after the completion of the Mission.

Appendix 3.2: Reproduced from Hedin & Bergman (1943a, p. 53) (Continued)

19. This English version is a literal translation of the Chinese text, which alone is held to be the official document.

The above agreement in nineteen articles was passed by the Federation at its 8th session on April 17th, 1927, and the Hon. Chou Chao-Hsiang is elected as the representative to discuss each article with Dr Hedin and to sign the agreement on behalf of the Federation, after being fully agreed upon by both parties, under the date April 26th, 1927, at Peking.

Appendix 3.2: Reproduced from Hedin & Bergman (1943a, p. 53) (Continued)

CONSTITUTION OF THE CENOZOIC RESEARCH LABORATORY OF THE GEOLOGICAL SURVEY OF CHINA.

(Peking, February 8, 1929)

1. The aim of this Laboratory is to carry on an extensive plan of human paleontological research; that is, the Laboratory aims to collect, study and describe fossils of Tertiary and Quaternary age in China with special reference to the problems of human paleontology.

2. The administration of the Laboratory is under the control of the Director of the Geological Survey with the assistance of the following persons:

Dr V.K. Ting: As Honorary Director of Cenozoic Research;

Dr Davidson Black: As Honorary Director of the Laboratory;

Dr C.C. Young (or another Chinese palaeontologist): As Assistant Director who will especially work on the paleontological part other than anthropological.

Other specialists may be appointed or asked by the Director of the Survey to collaborate in the work of the Laboratory.

3. A special fund will be granted by the Rockefeller Foundation to be dispersed through the Peking Union Medical College for the expenses of the Cenozoic Research.

4. All material collected shall entirely belong to the Geological Survey of China, including the anthropological specimens which will temporarily be deposited in the Peking Union Medical College for study and when kept by the Survey shall always be accessible for study by the Scientists of the former institution. Nothing shall be exported out of China.

The Cenozoic Research has no special interest in cultural studies and will not collect archaeological artifacts. Whenever artifacts of historic periods may be accidentally found, they shall be handed over to the proper Chinese museum.

Appendix 3.3: Reproduced from Jia & Huang (1990, p. 54)

CHAPTER 4

SCIENCE ACROSS CULTURES: THE CASE OF VERTEBRATE PALAEONTOLOGY IN CHINA

The first flourishing of vertebrate palaeontology in China occurred during the 1920's and 1930's as a result of the significance of the fossil record of the region for the study of the evolution of major mammalian groups. Following the multinational exploration of this record facilitated by the Geological Survey of China, considerable information about the fossil record and the biogeographical evolution of the region was collected, the Middle Pleistocene Peking Man site in Zhoukoudian was discovered, and a set of institutions specifically dedicated to the study of vertebrate palaeontology was founded in China.

This episode in the evolution of Chinese science has theoretical significance for historians of science, who have long been interested in the dynamics of the development of particular branches of scientific knowledge in specific places and at specific times. There are two approaches possible in this sort of analysis: one, the internalist approach, looks at explanations based on the cognitive and logical structure of scientific knowledge, while the second, the externalist approach, focuses on the social dynamics of scientific activity as well as the social context within which it is embedded. It soon became apparent to me, as I embarked on this study, that, in order to do justice to individual case histories, one needed to combine both, in what could be loosely described an ecological approach. Using this third approach, one could produce a multidimensional account of scientific activity and of the epistemological, cultural, sociopolitical and ideological spaces in which it is situated. This is particularly useful in a cross-cultural context.

In his foreword to the proceedings of the 1990 symposium on Science and Empires (Petitjean, Jami & Moulin, 1992), Patrick Petitjean highlighted the nature of the questions that need to be addressed in the emerging field of cross-cultural studies in history of science. These questions fall into two distinct categories: epistemological questions and historical questions. From an epistemological standpoint, one needs to have an idea of the nature of modern science or, more specifically, the characteristics of the field of science under study, and its demarcation from traditional knowledge systems. What are the links, modes of interaction and possible integration between traditional and modern science? What influence does the crossing of cultural borders have on cognitive processes? The historical questions concern the circumstances in which national scientific communities develop, the relationship of these communities with international science on one hand, and the local socio-economic system on the other.

In order to do justice to these questions, Petitjean called for more case histories to be subjected to several analytical approaches, which should be addressed from a double perspective: diffusion from the centre (and its means) and local emergence (and its context).

In this chapter, this entreaty can be used as a guide to interpret the case of the development of vertebrate palaeontology in China in the 1920's. This will take place in three stages:

1. The notion of model and a review of the main models that have been put forward to account for various examples of cross-cultural scientific transfers.
2. Summary of the main stages in the development of palaeontology in China in order to highlight the nature of the factors, vectors and local context of this development.
3. Suggestions for a dynamic model of the cross-cultural dissemination of science that will incorporate both internal and external factors.

4.1 - SCIENCE ACROSS CULTURES: A REVIEW

4.1.1 - "The spread of western science": the Basalla model

George Basalla (1967) was the first to attempt to model the pattern of events taking place when Western-style science became established in various parts of the world. His three-phase diffusionist model comprises an exploration phase, a colonial phase and an independent phase. The exploration phase is characterised by the opening up of a new area, which can act as a source of data for Western science. In China, the beginning of "phase-1 science" can be dated back to the arrival of the Jesuits in the sixteenth century; but, from the palaeontological point of view, it only started in earnest after the middle of the nineteenth century with, principally, the expeditions of the German geographer,

F. von Richthofen and, secondarily, those of the Russian geologist, V.A. Obruchev and the American geologist R. Pumpelly; the Central Asiatic Expeditions of the American Museum of Natural History (1916 – 1930), as well as the Sino-Swedish Expedition (1926 – 1935), can be interpreted on some level, as the finest flowers of "phase-1" palaeontology in China.

During "phase-2", the phase of colonial science, a local scientific community starts to develop, but the activities of this community are still very much framed by the Western interests that initiated it. The foundation of the Cenozoic Research Laboratory in 1929, a collaboration between the Peking Union Medical College and the Geological Survey of China, is a product of this phase, while the older Geological Survey of China (founded in 1916), can be interpreted as a product of "phase-3".

The transition to "phase-3", the phase of independent science is characterised by the replacement of the external scientific culture by a national one, the development of national scientific institutions, local education and employment of scientists and the opening up of new fields of study within this scientific community which can start acting as a centre for the diffusion of modern science. The beginning of "phase-3" could be equally well dated from the foundation of the Geological Survey of China in 1916 as from the creation of the Institute of Vertebrate Paleontology and Paleoanthropology (initially a laboratory of the National Planning and Steering Commission for Geological Works immediately after the founding of the P.R.C. in 1949. It became an integral part of the Chinese Academy of Sciences in 1953, was named the Institute of Vertebrate Paleontology in 1957 and renamed the Institute of Vertebrate Paleontology and Paleoanthropology (I.V.P.P.) in 1960). This ambiguity of beginning points towards one of the shortcomings of the Basalla model.

The Basalla model has often been criticised for its general character (failing to take into account specific national backgrounds and scientific disciplines) and its superficial treatment of the political context. However, it does offer a useful framework to approach these issues and is currently used, albeit with some reservations, by some Chinese historians of geology such as Yang (1991). There is also an internalist dimension to the shortcomings of

Basalla's model: its lack of cognitive focus, its failure to incorporate the epistemological dynamics of the cross-cultural episode under study.

4.1.2 - Science and imperialism: the MacLeod model

One of Basalla's critics, Roy MacLeod (1987), gave an account of the relationship between science and imperialism, and the associated cultural and economic interdependence. MacLeod attempted to correlate the main stages of imperial development with different aspects of scientific practice, institutional structures, social and political characteristics, economic and technological functions. He recognised five phases, based on his studies of Australia and other parts of the British Empire: a metropolitan (explorative) phase, a colonial phase (characterised by the initiation of locally-based research), a federative (cooperative) phase, an "efficient imperial" phase distinguished by the development of specialisation and local training and, finally, the "Empire or Commonwealth" phase, characterised by a growing independence of the colonial institutions. MacLeod's model is particularly useful in charting the political dimension of imperial science, the changing nature of vested interests both in Britain and in the colonies, as well as the complex nature of the cultural and economic interdependence associated with the natural history tradition. However, his model is still very much an externalist model, more concerned with the context of science than with its internal dynamics and its cognitive content.

4.1.3 - Colonial and national science: the Wade-Chambers model

David Wade-Chambers (1987) attempted to deal with the tension between the internalist and externalist dimensions of the periodisation schemes used by historians of science and the difficulty of choosing a useful historical framework for "colonial science". The rewards of constructing such a framework are great: a better understanding of the process of diffusion of ideas from one cultural setting to another, an easier cross-cultural comparison between various episodes of scientific development, an apprehension of the institutional framework necessary for this development. Wade-Chambers concluded that the road to a general framework for a cross-cultural history of science must be grounded in multiple case studies of the multi-dimensional network nature of science.

4.1.4 - The rose window model

In their Rose-Window model, Bruno Latour and Xavier Polanco (1990) have attempted to bridge the gap between the internalist and externalist approaches and integrate the contextual and epistemological aspects of scientific knowledge.

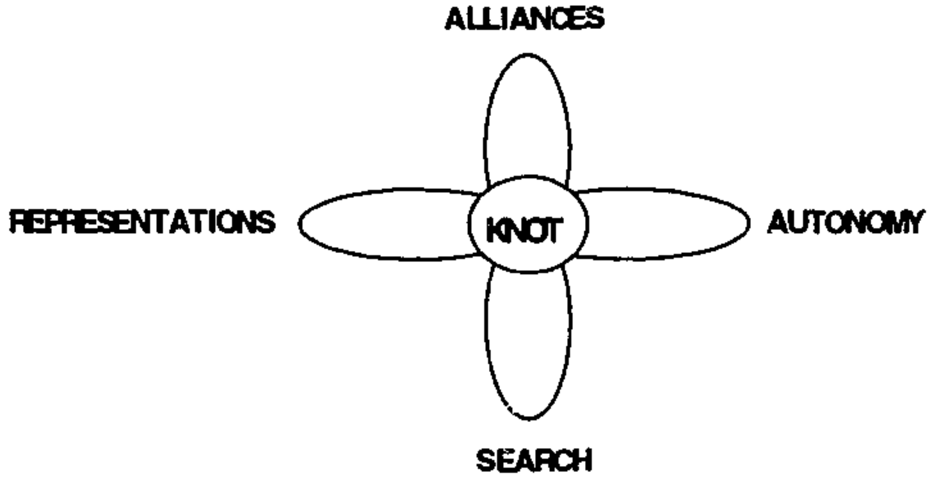


Figure 4.1 - The rose-window model (after Latour and Polanco, 1990)

This model is based on Polanco's concept of 'world-science' (Polanco, 1992), which itself is an adaptation of Fernand Braudel's concept of "world-economy" (Braudel, 1982 – 1984). In contrast to the more widespread concept of 'world science", which, in spite of its apparent neutrality, often refers to mainstream Western science, the phrase ' world-science' more specifically describes any autonomous section of global science capable of providing for most of its needs (journals, institutions, scientific community) and possessing an epistemological unity. Latour and Polanco's rose-window model (Fig.1) is a graphic representation of the network aspect of scientific activity; it comprises 5 interlocking circles and resolves the opposition between conceptual and social aspects, scientific content and scientific context.

The first circle (the 'search') represents the dynamic interaction between the natural world and science. In this study, the development of vertebrate palaeontology in China, the 'search' is the broad question asked from the Central Asiatic and Chinese fossil records and the means of this 'search': the exploration, collection and interpretation of the fossil record which produced answers to these questions.

The second circle ('autonomy') reflects the gradual emergence of institutions (training, research and publications) and the development of relationships with related disciplines. In the case of vertebrate palaeontology in China, 'autonomy' is represented by the foundation of the Cenozoic Research Laboratory, the development of palaeontological museums and the publication of the new journals produced by these institutions.

The third circle is the expression of 'alliances' with other social groups such as missionaries, interested laymen (informants) and also rich and influential groups such as the Geological Survey of China, the Swedish China Research Committee, the Rockefeller Foundation and the Science Society of China, which could facilitate the funding and growth of expeditions and institutions.

The fourth circle, is 'representation' or presentation of science to the public in such a way that ground will be laid for the acceptance of a particular theory or discipline by society at large, as well as the further support of the new 'world-science', locally and internationally. The voluminous output of scientific papers and monographs that resulted from the exploration and discovery of the fossil record of China in the first half of the twentieth century was accompanied by a no less impressive number of publications aimed at the general public as well as communications to granting institutions.

The 'knot' in the centre (the fifth circle) is formed out of the scientific results obtained and their success and fruitfulness in terms of the other circles: cognitive, institutional, public and representational. It is the dynamic and vital core of this model, whose growth is a reflection of the strength of the discipline under consideration. It is, according to Latour and Polanco (1990, p.65), this knot that

> ...Ties the other elements strongly in order to prevent them from scattering in all directions under the influence of centrifugal forces. All these heterogeneous factors are always on the verge of betrayal: nature becomes incomprehensible again, colleagues lose their commitment, allies lose patience or interest, the public prefers ignorance. The more the factors, the more important it is to find the notion, the argument, the theory that will tie them all together. The strength of this knot is critical for the persistence of the system.
> (translated from the French by the author)

4.1.5 - The constructivist approach

The models which have been reviewed in the preceding sections were selected on the basis of their relevance to the subject under study; they constitute a very small fraction of those that have been proposed to account for the dynamics of scientific activity, in terms that go beyond the classical, linear, epistemological approach that is predicated upon the gradual uncovering of natural laws. In the past decade, the literature focusing on the analysis of these 'extra-epistemological' factors has grown steadily (Thackray, 1995, Kuklick & Kohler, 1996; MacLeod, 2000). These factors include: moral values, gender, chronology and geography, disciplines (Thackray, *ibid.*), field work (Kuklick and Kohler, *ibid.*), colonialism and post-colonialism (MacLeod, *ibid.*).

All these approaches have one point in common: they are attempting to analyse the factors that participate in the 'construction' of scientific knowledge and have been described as 'constructivist' in outlook. According to Golinski (1998, p. ix), the constructivist outlook "regards scientific knowledge primarily as human product, made with locally situated cultural and material resources, rather than as simply the revelation of a pre-given order of nature". The constructivist approach has developed from the response to Thomas Kuhn's work on scientific revolutions (Kuhn, 1962) and the succeeding studies in the sociology of science and is aimed at the "uncoupling of historical and sociological inquiry from issues of truth, or realism, or objectivity" (Golinski, 1998, p. x). In other words, far from being an attack on the legitimacy of science as a way of knowledge, it has enlarged the view of science and incorporated into it new elements, which need to be taken into account by the historian of science in order to produce a richer, multifaceted account of their chosen episode in the history of science. Among the elements described by

Golinski (*ibid.*), some are particularly relevant to the episode under study in this thesis: the development of vertebrate palaeontology in China at the turn of the twentieth century. These factors are:

- the social environment and its implications for the deciphering of the fossil record,
- the social identity of individual scientists
- the development of disciplinary structures
- the dynamics of fieldwork
- the interaction between scientific culture and general culture

These elements can be added to (integrated with) those already present in the rose-window model described in the preceding section.

4.2 – THE DEVELOPMENT OF VERTEBRATE PALAEONTOLOGY IN CHINA – A CONSTRUCTIVIST ANALYSIS

4.2.1 – The central motif: palaeontological, geological or social?

The fossil record

The first flourishing of vertebrate palaeontology in China has been described in this thesis as the result of the significance of the fossil record of the region for the study of the evolution of major mammalian groups, including hominids. Indeed, the launching of the Central Asiatic Expeditions by the American Museum of Natural History had, as one of its main aims, to provide evidence for the biogeographical ideas proposed by H.F. Osborn, the President of the American Museum of Natural History (Osborn, 1910) and developed by Matthew (1915). As a result of these expeditions, Osborn's and Matthew's hypothesis was confirmed, knowledge of the fossil and geological record of central Asia had considerably increased and Central Asia was shown to have been a major centre for the evolution, not only of mammals, but also reptiles.

The fossil record of China also revealed its riches to a number of other foreign scientists as a result of a larger, or different project: the work of Teilhard de Chardin and the Sino-Swedish Expedition led by Sven Hedin, falls within this category. Teilhard de Chardin first came to China on the invitation of Père

Emile Licent, a fellow Jesuit, who was setting up a natural history museum (the Hoangho Paiho Museum), at the Jesuit College in Tianjin (see Chap. 3, Para. 3.1). The presence of Licent in China was part of the larger Jesuit project (with a long history in China) to convert and educate through the development of Christian and scientific centres. This was the beginning of Teilhard de Chardin's Chinese phase (1923 – 1946) during which his scientific and theological contributions were immense. After his collaboration with Licent (1923 – 1928), he gradually developed an association with the Geological Survey of China and became involved with the Cenozoic Research Laboratory and its study of Peking Man (1929 – 1936). During this period, as his geological and palaeontological reputation grew, he took part in the 1930 season of the Central Asiatic Expeditions and Haardt-Citroen Croisière Jaune (whose primary aim was certainly not scientific). During the last period of Teilhard de Chardin in China (1939 – 1946), made longer than intended by the Second World War, Teilhard de Chardin founded the Institute of Geobiology with fellow Jesuit Père Pierre Leroy. The range of his contributions to vertebrate palaeontology in China resulted in more than 300 papers on the subject of Late Cainozoic stratigraphy (based on the fossil vertebrate content), palaeontology and palaeoanthropology of the Zhoukoudian site and large-scale tectonic studies of the evolution of the Asiatic continent and its bearing on the evolution of Asiatic faunas. The range of his contribution reflects the multi-faceted nature of his interests, as well as the range of activities with which he became involved during his Chinese period.

Sven Hedin was primarily an explorer, an exemplar of the well-established tradition of explorer-naturalist, keen to discover and map the unexplored parts of the globe, to record its fauna, flora and cultures, a tradition that had already brought Vladimir Obruchev and Ferdinand von Richthofen (among others) to China and Central Asia. Indeed, Hedin had studied under von Richthofen, and his Central Asiatic interest had been greatly influenced by von Richthofen, who became a life-long friend. The Sino-Swedish Expedition, in its original form, grew out a combination of factors (see Chap. 3, Para. 3.2):

- Sven Hedin's international reputation as an explorer (following three successful and well documented expeditions into Central Asia),

- his search for funds for yet another expedition in the region and the desire, on the part of the Deutsche Lufthansa to establish a Germany – China air route,
- the lengthy negotiations with the Chinese government of the day facilitated by the geologist and fellow Swede John Gunnar Andersson and the head of the Geological Survey of China, Wong Wenhao,
- the resulting contract with the Chinese government, which resulted in the Sino-Swedish collaboration that became the central feature of the three phases of the expedition and provided for a wide range of scientific endeavours within the expedition: from archaeology to meteorology, geology, palaeontology and biology.

The geological record

Palaeontology is the study of the palaeobiological dimension of the geological record and is founded on an understanding of the geological history of the Earth; it is then not surprising that the two sciences of palaeontology and geology should develop in tandem, although, because of its economic importance, geology did have a head start in China.

Johan Gunnar Andersson was the Director of the Geological Survey of Sweden when he was invited by the Chinese Government, in 1914, as a mining adviser on the exploration and exploitation of Chinese ore deposits (see Chap. 3, Para. 3.3). Andersson was also a man of many interests (after the generalist naturalist tradition), specifically fossil collection and archaeology according to his own account (Andersson, 1934). These interests, coupled with the travelling requirements of his geological activities, his association with the Geological survey of China as well as the Geological Survey of Sweden, the Swedish Museum of Natural History and the University of Uppsala (Sweden), ensured that the growing collection of fossil material he had gathered was described and published in a new set of publications Paleontologia Sinica, jointly funded by the Geological Survey of China and the Swedish Government (out of the China Research Fund). Swedish and Chinese interests in the conservation of specimens were also negotiated by means of a contract according to which original specimens of plants and vertebrate fossils returned to China after duplicates were made in Sweden, and invertebrate fossils were duplicated in China under the supervision of Amadeus Grabau in Peking University and duplicates sent to Sweden.

The growing Chinese interest in developing Chinese ore resources was also responsible for the development of geological education and institutions that was charted in Chap. 1 (Para. 1.3). As a result, the Geological Survey of China was set up in 1916, under the impetus (and direction, in turns) of Ting Wenchiang and Wong Wenhao, and the first University Department of Geology was set up at Peking University in 1918. Two of its early members, Amadeus Grabau and J.S. Lee nurtured it into a prominent partner in the geological world of the 1920's and 1930's. Professor Grabau, in particular, became closely associated with two of the groups involved in the ongoing palaeontological program: the Geological Survey of China (Grabau was the Chief Palaeontologist at the Geological Survey of China) and the Central Asiatic Expeditions (Grabau participated as a research associate).

Socio-cultural factors

The development of geological and palaeontological science in China at the beginning of the twentieth century is firmly grounded in the socio-cultural transformation that was taking place in China at the time, the transition from the dynastic age to the republican age, and the emerging interest in western science and technology that resulted from a succession of defeats attributed in part to China's weakness in front of western technology (See Chap. 1). It is also the fruit, of foreign socio-cultural factors: these were religious and political in nature and served geopolitical objectives.

The Jesuit presence in China since the sixteenth century, and the presence at the end of the nineteenth century of a large number of missionaries from a variety of Christian denominations have had effects on Chinese culture and society that range far beyond the initial religious endeavour. They were instrumental in the initial introduction of western science and technology and the development of technical and scientific training in educational institutions. The presence of Licent and Teilhard de Chardin in China is directly related to their Jesuit vocation. A more indirect effect of the missionary presence in China on palaeontological investigations is the vast number of missionary posts in regional and remote places of the Chinese continent: they served, as it were, as an informal network of contact points for the growing number of western palaeontologists travelling in the interior of China, providing material support and relief as well as information grounded in their local knowledge. There are many references in the narratives of the Sino-Swedish Expedition and the Central Asiatic Expeditions to such encounters.

According to Buck (1980), the development of the Peking Union Medical College, like the Boxer Indemnity Fellowship Program, was the fruit of a determination, on the part of the United States, to affect China's future by means of education and institutional development, "to train an enlightened Chinese elite competent to guide their country's development, on the one hand; and to create the institutional resources necessary for that elite to function successfully" (Buck, *ibid.*, p. 48). This twin aim succeeded brilliantly, albeit in a somewhat serendipitous fashion, in providing an institutional home for the Cenozoic Research Laboratory, as a result of the presence of Davidson Black on its faculty. Davidson Black' s contribution to the description of Peking Man and the genesis of the Cenozoic Research Laboratory has been detailed in Chapter 3 (see Para. 3.5.2).

These programs were grounded in an increasing involvement of the United States in Asia at the turn of the twentieth century, manifested by the annexation of the Philippines in 1898 and the Open Door policy in China in 1898. The 'Open Door and Equal Economic Opportunities' policy was originally designed by the U.S. in order to prevent China from being carved up into separate spheres of influence by the series of treaties that took place at the end of the nineteenth century, and to allow access by all participating countries to each other's spheres of influence. It was followed, in 1914, by the full diplomatic recognition of Yuan Shikai's government by the United States (Spence, 1990; Chen, 1979). These two measures encouraged American entrepreneurs to invest into China's economic development and, in turn, greatly facilitated Roy Chapman Andrews's efforts to fund the Central Asiatic Expeditions (Rainger, 1991). Upon Henry Fairfield's Osborn's advice, he successfully approached, for financial support, the wealthy patrons of the

American Museum of Natural History, who were also the entrepreneurs of the day, people like J.P. Morgan Jr, Childs Frick and John D. Rockefeller Jr, who are listed in Andrews (1932), along with over 600 other financial contributors to the expeditions.

Summary

The central motif, or 'knot', according to Latour & Polanco (1990), has thus been found, in its initial phase, to be made of three interacting streams: palaeontological, geological and socio-cultural. The socio-cultural conditions can easily be defined as contextual to the scientific enterprise under study; the palaeontological and geological aspects of the central motif contain epistemological and contextual (or, according to the classical description, internal and external) elements: these are respectively, the exploration of the fossil and geological record, and the institutions and circumstances that made this exploration possible.

4.2.2 – The palaeontological enterprise: A dynamic perspective

The exploration of the Chinese vertebrate fossil record between 1920 and 1940 and the subsequent development of the community of Chinese vertebrate palaeontologists are the fruits of many elements that affected the central motif outlined in the previous section.

Individuals

In the constructivist and sociological literature, the role of individuals in the making of scientific knowledge has often been subsumed to their social matrix (the scientific community and/or the general community). Golinski (1998), for example, refers to the formation of the identity of the scientific practitioner (p. xii), and describes how "understandings of 'nature' are products of human labor with the resources that local cultures make available" (p. 47). There is, though, another important dimension to the involvement of particular individuals in field sciences (like palaeontology and geology) where data are collected in sometimes distant and remote places (like China), and this dimension is quite an integral part of their identity as scientists: the exploring impulse, sometimes grounded in a rejection of or discouragement with prospects in one's native environment (Belorgey, 1989), sometimes grounded in an intense curiosity for the exotic, which becomes the very career of the explorer (Said, 1978). One of the delights of this research has been the "meetings with remarkable men" (Gurdjieff, 1963), men like Teilhard de Chardin, Sven Hedin, Roy Chapman Andrews, Davidson Black, among others, who followed their particular call to the region, found and/or described its fossils, interacted with a group of Chinese scientists, many of whom had done the reverse trip to the West, and, in the process, nurtured a new scientific community into being.

Evidence for this exploring impulse is readily available in the autobiographical/biographical by and about these men and illustrates the various forms of this impulse:

- a delight in the natural world and a spiritual inspiration for Teilhard de Chardin, the source of the scientific aspect and the spiritual aspect of his work:

> I have glimpsed and greedily 'drunk in' the East – not its people and its history (which don't interest me as yet), but its light, its vegetation, its fauna, its desert.
> (Teilhard de Chardin, 1962, p. 13)

> What really concerns him, in the leisure of his tent when the sun has gone down on the limitless landscape of Mongolia, is the new writing on which he is now at work. He calls it 'my Mass upon things' and goes on to reveal....the heart of his inspiration:
>
> > "It seems to me that in a sense the true substance to be consecrated is the world's development during that day – the bread symbolizing appropriately what creation succeeds in producing, the wine (blood) what creation causes to be lost in exhaustion and suffering in the course of this effort".
>
> (Speaight, 1967, p. 127)

- the choice between the academic path and the explorer path for Sven Hedin:

> Richthofen was expecting much from me but I had already been to Asia. The splendour and beauty of the Orient had fired my imagination; I loved the silence and the solitude of the desert. I had no inclination to spend my time in university halls. Richthofen

wanted me to fill the gaps in my geological knowledge; indeed, those haunted me during my explorations in Asia. While I was in Berlin, I found myself at a crossroads: either I continued with my studies and became an expert geologist, or I followed the call of my vocation and became a pioneer who opened up unexplored areas of Central Asia that would be studied later by specialists. I chose the latter.
(quoted in Kish, 1988, p. 35)

- a "restive" nature at the core of Roy Chapman Andrews's vocation as an explorer-naturalist:

During my years at the Museum I almost never returned from an expedition without having plans ready for another.

....

Sometimes when I walked across Central Park on a starlit summer night I used to look up at the drifting clouds, going with them in imagination far out to sea into strange new worlds. Then I would count the days that still remained before I could set my feet upon the unknown trails that led westward to the Orient
(quoted in Gallemkamp, 2001)

- a scientific problem that changed Davidson Black's life upon reading Climate and Evolution, by W.D. Matthew (1915) according to a testimony by one of his close friends, Paul Huston Stevenson:

There can be no doubt that from this time on the problem of the origin and early evolution of man occupied first place in Black's mind. Immediately the scattered rays of previous interests came to a clear focus on this fascinating subject. He recognized at once that here was an opportunity for full investment of his unique capital in life, his inherent love of adventure, his instinct for discovery, even more his practical geological experience and perspective and his extensive knowledge of comparative anatomy in particular. All his previous interests and experiences immediately fell into their self-appointed places in the broad foundation of correlated qualifications that guided his approach to the new problem now uppermost in his mind.
(quoted in Hood, 1964)

The exploring impulse is an important element in the individual make-up of all scientists when it is described as a search for understanding (Goldstein & Goldstein, 1984), but in its geographical expression, it orients the search for understanding towards distant natural places which become the locus of the field experience.

The field experience

The study of the specific characteristics of science in the field form the subject of a recently growing body of literature after having long been neglected in favour of the study of laboratory science. According to Kuklick & Kohler (1996), field sciences are defined by the experience of natural places where "practices in the field sciences depend on the conditions in these places, requiring considerable improvisation to cope with local exigencies. They involve a socially diverse array of practitioners and put a premium on craft skill." (p. 2). Kuklik and Kohler (*ibid.*) list a series of challenges that have to be met in the field; field scientists "must attend to the exigencies of getting to and staying in the field; to the affective aspects of natural places; to the heterogeneity of field science workers and tasks" (p. 3).

There is no doubt that the field experience in China and Central Asia was of critical importance in the collection of data on the fossil record, as it is in the collection phase of any palaeontological or geological project. Three aspects are especially interesting:

- the modalities of access to the field

The collection of fossils took place in a wide range of circumstances and styles, from the fairly simple style found in the French, Swedish and Chinese field expeditions to a more highly structured style of the Central Asiatic Expeditions and Sino-Swedish Expeditions. In the early 1920's, the two French Jesuits, Emile Licent and Pierre Teilhard de Chardin relied on local resources and their contacts in the countryside.

> Teilhard and Licent presently set out from Tiantsin by train with their twelve packing cases, two hampers, camp beds, saddles and servants. The first day brought them to Kalgan and the second to Kwei-Hoa-Tcheng. The basaltic plateau was very reminiscent of Auvergne, except that the fields were dotted with irises instead of gentians. At Kwei-Hoa-Tcheng, they were welcomed by the Belgian missionaries, and also by General Ma-Fou-Sian, the local and omnipotent mandarin, who authorized them to cross the Yellow River and explore the Ordos. This desolate and plague-stricken country was the

> object of their journey, and it lay slightly to the south, enclosed within a bend of the great river. It was also menaced by bandits. A caravan was therefore organized, comprising ten mules, three donkeys, five donkey-boys, and two soldiers for escort. Ten guns were available for self-protection, and for shooting the pheasants, hares and gazelles which abounded in the country through which they were to pass.
> (Speaight, 1967, p. 124)

In contrast, the Central Asiatic Expeditions were well-structured efforts, involving large numbers of participants (scientists, technicians and interpreters) organised in field units which could work independently. Roy Chapman Andrews was a believer in the "method of correlated work", an early expression of the multidisciplinary approach and was delighted with its success. One of the challenges faced by the Expedition was the physical conditions of the Mongolian region: its remoteness, its great distances and the severity of its climate; as a result, motor transport was chosen, assisted by camel caravans sent ahead to drop fuel and other supplies at pre-arranged points. According to Andrews (1932, p.14):

> We have been referred to as a "de luxe" expedition because we had the maximum of camp comforts. I may say, however, that there was not one item of unimportant equipment. In the field were a group of men who worked at high tension for nearly six months. An army cannot fight unless it is well fed; neither could our men have accomplished what I expected of them unless they were kept physically fit.
>
> ...
>
> I do not believe in hardships, if they can be avoided, for they lessen effectiveness; they are a great nuisance.
>
> ...
>
> Neither do I believe in adventures. Most of them can be eliminated by foresight and organization.

Andrew's philosophy of fieldwork was certainly vindicated by the good health record of all the participants, and the impressive nature of the field results (see Chap. 3, Para 3.4.2).

The Sino-Swedish Expedition was also a well-structured effort campaign and, in many ways, similar in inspiration, a point that was noted by Sven Hedin (Hedin & Bergman, 1943, p. 60). However, there are interesting logistic differences: the main one was the use of motor cars in the Central Asiatic Expeditions while the Sino-Swedish Expedition used camels for transport. This was dictated by the respective terrains faced by the Expeditions and, in turn, made possible Andrews's choice of the 'method of correlated work', while the different teams worked much more independently in the Sino-Swedish Expedition. These different styles also suited the different aims of the two Expeditions: the main aim of the Central Asiatic Expedition was palaeontological while the overall aim of the Sino-Swedish Expedition was much broader, and changed with time, according to the brief of each of its three periods (See Chap. 3, Para.3.2.2).

- the 'dragon bone' connection or the importance of informants

The traditional use of fossils ('dragon bones') in the Chinese pharmacopoeia has already been noted and has had important implications for the discovery of fossil localities, starting with the material described in Schlosser's seminal study (Schlosser, 1903), and originally collected from apothecaries. According to Jia & Huang (1990), dragon bones have had an enduring relationship with vertebrate palaeontology, from the discovery of the Zhoukoudian (Peking Man) site to the discovery of the in-situ deposit of the giant ape (*Gigantopithecus*), in 1956, in the Guanxi Zhuang Autonomous region in southern China, and the discovery of the Lantian Man site in 1963 in Shaanxi.

> In 1963, another team from the Chinese Academy of Sciences made discoveries of great significance in Lantian County, Shaanxi Province, in much the same fashion. The scientists involved were Zhang Yuping, Huang Wanpo, Ji Hongxiang and Tang Yingjun . . . When the team arrived at Gongwang Village, 16 kilometres from the county seat of Lantian, a sudden rain forced the members to look for shelter at a roadside store. They joined villagers who had gathered there to get out of the rain. Conversation promptly turned to the subject of dragon bones. " Right on the edge behind this village, you can find plenty of them " said one of the villagers. So the team stayed, and in three days they recovered five boxfuls of fossils. Because of this initial success, the Academy of Sciences sent a larger team to the village the following year, and that was when they found the Lantian Man skullcap.
> (Jia & Huang, 1990, p. 7)

The saleable nature of vertebrate fossils also had less fortunate consequences in terms of preservation, a fact that is acknowledged and lamented by Jia & Huang (1990), although the actual extent of the damage is difficult to evaluate.

The discovery of the Zhoukoudian (Choukoutien) site is similarly due to informants. In his account of his palaeontological and archaeological explorations in China, Johan Gunnar Andersson (1934, p.95) relates how a site had been pointed out to him in 1918 by his friend, J. McGregor-Gibb, who was teaching chemistry at Peking University. The site was Jigushan (Chicken Bone Hill), near Zhoukoudian, thus named because of the abundance of bird bones it contained. On a visit to the site, in 1921, with Otto Zdansky and Walter Granger, they were approached by a local resident, who took them to another site, 150 metres away, where they could "collect much larger and better dragon bones". This new site ultimately yielded the first human fossil as well as a variety of other vertebrates, and, it could be argued, was the birthplace of the Chinese palaeontological community (See Chap. 3, Para. 3.3).

- the challenge of a society in the cusp of change

One of the most challenging aspects of field work in China during the first half of the twentieth century was the ongoing struggle of China to free itself from its imperial past and engage on the republican path, while facing external threats and internal rebellions (See Chap. 1, Para. 1). During this period of transition, conditions became highly unstable and unpredictable, especially during the Warlord Era (1916 –1927), between the death of Yuan Shikai in 1916 and the Nationalist period (1928 – 1937), and the ensuing Japanese invasion in 1937 and the Sino-Japanese War (1937 –1945). In 1938, Chongqing, in the southern province of Sichuan, became the capital of China where most of the national institutions moved, including the Geological Survey of China.

One of the most celebrated casualties of these circumstances is the disappearance of the fossil remains of Peking Man in 1941. But the impact on the palaeontological enterprise was constant during the 1920's and 1930's. It took two main forms: travelling and living conditions in the field were constantly affected by what had become a large-scale civil war; and there was intense distrust of foreign scientists, especially those aiming at working independently of Chinese institutions. As a consequence, three distinct agreements were negotiated between the Chinese and the Cenozoic Research Laboratory (see Chap. 3, Para 3.6 and Appendix 3.3), the Sino-Swedish Expedition, which became a joint expedition precisely as a result of the rising opposition to foreign expeditions (see Chap. 3, Para 3.2 and Appendix 3.2) and the Central Asiatic Expeditions which were confined to Mongolia for the same reason (see Chap. 3, Para. 3.4).

As a result of the Sino-Japanese war and the relocation of the Geological Survey to Chongqing, central and south-western China became the focus of palaeontological work; this is reflected strongly in C.C. Young's work during this period when research on the Triassic reptiles of the Lufeng Basin in Yunnan Province (southern China) figures prominently.

Funding

Funding of the palaeontological enterprise in China in the 1920's and 1930's was, in keeping with the international nature of the projects, of multiple origin, as was described in the survey of the different elements of that enterprise (See Chap. 3).

- The government – sponsored French Palaeontological Mission to central China was the initial support of Teilhard de Chardin's work in China until his nomination in 1929 as a scientific adviser to the Geological Survey and his involvement with the developing program at Zhoukoudian.

- Financial support for the three phases of the Sino-Swedish Expedition was different, reflecting their different aims: the first expedition, initially a reconnaissance of the Germany - China air route was funded largely by the Deutsche Lufthansa aeronautical company; the second expedition whose main aim was scientific, was financed primarily by the Swedish government (by means of the China Research Committee), although sizable contributions were provided by Lufthansa and private individuals; the third expedition was financed primarily by the Chinese government. The Swedish China Research Committee, of which the Crown Prince of Sweden was the Chairman, financed most of the Swedish projects in China, starting with Johan Gunnar Andersson's work.

- The growing interest of Johan Gunnar Andersson in palaeontology and archaeology while prospecting ore deposits on behalf of the Chinese Government resulted in the necessity for Andersson to find resources to finance the collection and description of the specimens. Andersson was able to obtain initial funding from Axel Lagrelius, Chief Intendant at he Swedish Court and a wealthy man who had already supported various projects in natural history research (Andersson, 1929). As the Swedish involvement in the Chinese region grew and requests for funds became more numerous, the Swedish China Research Committee was set up, initially to obtain and distribute funds and, in time, to provide a home for the collections that were brought back from China. Thus the Museum of Far Eastern Antiquities in Stockholm was born, and the Lagrelius collection of Chinese vertebrate fossils constituted. The Lagrelius collection is now housed at the Palaeontological Museum of the University of Uppsala; it is the largest collection of Chinese vertebrates outside China and has been the subject of a large number of scientific papers (Mateer & Lucas, 1985; Schöbel, 1985).

- Funding for the Central Asiatic Expeditions was very much the result of Roy Chapman Andrews's efforts (and Henry Fairfield Osborn's advice) and came primarily from individual donations (See Para. 4.2.1), although four institutions are listed in Andrews (1932, p. 631): the Sociedad Estudios Biologicos in Chapultepec (Mexico), the Field Museum of Natural History in Chicago (Illinois), Northwestern University, Evanston (Illinois) and, from the beginning, the American Museum of Natural History and the American Asiatic Association in New York. Most of the smaller individual donations came from the

United States, but some came from places as far afield as Argentina, England, India, Japan, Mexico and Rumania, and two from China. The bulk of the smaller donations came in as a result of the infamous "Great Dinosaur Egg Auction" held in January 1924: the egg itself fetched $ 5,000, but donations totaling $ 50,000 flowed in as a result of the publicity surrounding the auction (Gallenkamp, 2001). This publicity also had the negative result of intensifying the antagonism of the Chinese Society of the Preservation of Natural Objects, which resulted in the restrictions put on the activities of the Central Asiatic Expeditions from 1928 onwards (Andrews, 1932).

- The funding history of the Zhoukoudian project is a complex one and includes three main sources: the Swedish China Research Committee, which financed the work of John Gunnar Andersson, Otto Zdansky and Birger Bohlin; the Geological Survey of China through the contract established with Andersson (See Chap. 3, Para. 3.3); and the Rockefeller Foundation which funded the Peking Union Medical College where the description of Peking Man was made by Davidson Black (See Para. 3.5). As a result of the discovery of Peking Man and the subsequent efforts of Black and Andersson, a collaboration was set up between the Geological Survey of China and the Rockefeller Foundation and the Cenozoic Research Laboratory founded with a two-fold aim: the excavation program at Zhoukoudian and the study of the Plio-Pleistocene mammalian fauna in that site (See Para. 3.6).

Funding of the palaeontological enterprise in China in the 1920's and 1930's had many origins, reflecting the varied backgrounds of the participants and their different interests. It was, as in other scientific enterprises, dependent primarily on the relevance of the project under consideration to the interests of the funding body and continued on the basis of results obtained. The combination of the Swedish China Research Committee, the Geological Survey and the Rockefeller Foundation points to the central importance of that new institution, the Cenozoic Research Laboratory, not only for the international scientific community, but also for the Chinese growing scientific community, for which it became the home, not only of Peking Man, but also, of vertebrate palaeontology.

4.2.3 – The central motif revisited: The legacy

The first examination of the central motif (Para. 4.2.1) has provided an initial picture in terms of the three streams (palaeontological, geological, and socio-cultural) of the palaeontological enterprise in China in the 1920's and 1930's.

This initial picture has been altered during the twenty-year period by the actual exploration of the fossil record that took place during that time and the results obtained, in scientific and institutional terms; this has been the subject of Chapter 3. This period of growth of vertebrate palaeontology has been grounded in the personal motivations of the participants, the challenges of the natural and social worlds, the interaction, collaboration and competition between individuals and their personal and institutional networks and, last but not least, the availability of funding.

The final picture of the central motif is the legacy of that period of growth: the impact on palaeontological thinking and the development of a palaeontological community in China. The impact on palaeontological thinking was both direct (knowledge of the fossil record of the region was increased, and the hypotheses of Osborn (1910) and Matthew (1915) confirmed) and long-lasting (forming the basis of recent developments in the palaeontology of the region, especially concerning Mesozoic palaeoherpetology, Cainozoic palaeomammalogy and Quaternary palaeoanthropology: See the Conclusion of Chap. 3 for a review of these).

The institutional impact of the palaeontological enterprise was very much shaped by the success of the initial exploration of the fossil record and the historical circumstances of the region during that period. The Cenozoic Research Laboratory was both the training ground and the first form of the Institute of Vertebrate Paleontology and Paleoanthropology that is now the flagship of Chinese palaeontology and palaeoanthropology. The central motif is now ready to undergo further changes, which form the subject of the history of vertebrate palaeontology in what has become the People's Republic of China.

4.3 – CONCLUSION

The case of the development of vertebrate palaeontology in China has been analysed from a constructivist point of view, highlighting the close relationship between internal (palaeontological) factors and external (socio-cultural) factors. The Rose Window model (Latour and Polanco, 1990) has been extended to include individual, practical (the field experience) and financial factors. The central thesis of Latour and Polanco (*ibid.*) is that the development of scientific disciplines across cultures can best be accounted for in terms of social history of science, that the social context of scientific activity must not be divorced from its epistemological core, and that both the initial and final states of the central "knot" (motif), and the transforming process between the two stages, are multidimensional. The contribution of the constructivist approach was in the identification of the main elements pertaining to the transformation process.

The implications and limitations of such a model are determined by the intrinsic characteristics of a model. According to Bullock *et al.* (1988), the purpose of a model is three-fold: firstly, to act as a reminder of the original; secondly, to make predictions and encourage discovery (in an experimental context) and, thirdly, to provide explanations. This is achieved by the mapping of elements in the system under study onto the model where, because of the complexity of the original system, some degree of simplification occurs. Because of the historical nature of the case study which is the subject of this thesis, the main purpose to be achieved in such a model is an explanatory one and a secondary purpose may be to use the model to decipher other case studies which may present similar questions.

The first explanatory function of the constructivist model was fulfilled. Applied to the Latour and Polanco model, it allowed the successful integration of the network of factors at work in the development of vertebrate palaeontology in China:

- the epistemological drive to explore the Chinese and Central Asiatic fossil vertebrate records
- the regional nature of palaeontology and its association with an existing geological network
- the multinational interaction, collaboration and competition between individuals and their personal and institutional networks
- the historical framing of this First Golden Age of Chinese Vertebrate Palaeontology between the agony of the Chinese Empire and the Japanese invasion

The secondary function of the model, its applicability to similar case studies, remains to be assessed. Lines of further inquiry fall into two categories:

1. the development of vertebrate palaeontology in other non-Western countries such as Russia, India, Japan, South America and Australia, where special factors are operating such as

- Russia: the influence of Marxist ideology and the special relation between the U.S.S.R and China during the 1950 – 1960 period
- India: the colonial situation and the Hindu world-view (and its influence on Indian science and view of nature)
- Japan: the Chinese heritage and the distinct historical background
- South America, South Africa and Australia: the Gondwanan fossil record and the colonial situation.

2. the development of non-palaeontological scientific communities in China, where relevant factors are:

- timing and its sociocultural implications,
- the fundamental versus applied/regionally-based nature of the science,
- the relationship to vertebrate palaeontology.

Disciplines of interest include: geology, chemistry and medicine, about which there is a growing body of literature. The case of medicine is especially interesting because of its institutional connection with the early development of vertebrate palaeontology (at the Peking Union Medical College) and its interaction with a fully developed medical tradition based on a different paradigm (traditional Chinese medicine); geology has been seen, in this study, to have acted almost as a host to the newly developing community of vertebrate palaeontology and, although, the history of its development has been alluded to in connection to palaeontology, it certainly warrants a study of its own.

REFERENCES

ANDERSSON, J.G., 1934: *Children of the Yellow Earth.* Kegan Paul, Trench, Trubner & Co. Ltd, London.

ANDREWS, R.C., 1932. *The New Conquest of Central Asia – A Narrative of the Explorations of the Central Asiatic Expeditions in Mongolia and China, 1921 – s1930.* The American Museum of Natural History, New York.

BASALLA, G, 1967. The spread of Western science. *Science* 156, pp. 611-622.

BELORGEY, J.-M., 1989. *La Vraie Vie Est Ailleurs – Histoires de Ruptures avec l'Occident.* J.-C. Lattès.

BUCK, P., 1980. *American Science and Modern China 1876 – 1936.* Cambridge University Press.

BRAUDEL, F., 1982 – 1984. *Civilization and Capitalism, 15^{th} –18^{th} century.* Collins, London. 3 vols.

BULLOCK, A., STALLYBRASS, O. & TROMBLEY, S., 1988. *The Fontana Dictionary of Modern Thought.* Fontana Press.

CH'EN, J., 1979. *China and the West - Society and Culture 1815 - 1937.* Hutchinson of London.

GALLENKAMP, C., 2001. *Dragon Hunter – Roy Chapman Andrews and the Central Asiatic Expeditions.* Viking.

GOLDSTEIN, M. & GOLDSTEIN, I., 1984. *The Experience of Science – An Interdisciplinary Approach.* Plenum Press, New York and London.

GOLINSKI, J., 1998. *Making Natural Knowledge – Constructivism and the History of Science.* Cambridge University Press, U.K..

GURDJIEFF, G.I., 1963. *Meetings with Remarkable Men.* London.

HEDIN, S. & BERGMAN, F., 1943. History of the Expedition in Asia 1927 – 1935. Part I: 1927-1928. *Reports from the Scientific Expedition to the North-Western Provinces of China under the Leadership of Sven Hedin – The Sino-Swedish Expedition.* Publication 23.

HOOD, D., 1964: *Davidson Black - A biography.* University of Toronto Press.

JIA, L. & HUANG, W., 1990. *The story of Peking Man – From archaeology to mystery.* Foreign Languages Press, Beijing and Oxford University Press, Hong Kong.

KISH, G., 1988. *Tibet au Coeur – La Vie de Sven Hedin*. Editions R. Chabaud – Peuples du Monde.

KUHN, T.S., 1962. *The Structure of Scientific Revolutions.* University of Chicago Press.

KUKLICK, H. & KOHLER, R.E., 1996. Science in the Field. *Osiris* Vol. 11, The University of Chicago Press.

LATOUR, B. and POLANCO, X., 1990. A propos de l'histoire sociale des sciences: Quelques remarques, le modèle de la rosace. *In* Polanco, X. (Ed.): *Naissance et développement de la science-monde - Production et reproduction* *des communautés scientifiques en Europe et en Amérique Latine.* Editions La Découverte, Paris, pp. 10-52.

MACLEOD, R., 1987. On visiting the "moving metropolis": Reflections on the architecture of imperial science. *In* Reingold, N. and Rothenberg, M. (Eds): *Scientific colonialism - A cross-cultural comparison*, Smithsonian Institution Press, Washington, D.C and London, pp. 217-249.

MACLEOD, R., 2000. Nature and Empire – Science and the Colonial Enterprise. *Osiris* Vol. 15, The University of Chicago Press.

MATEER, N.J. & LUCAS, S.G., 1985. Swedish vertebrate palaeontology in China: A history of the Lagrelius Collection. *In* S.G. Lucas and N.J. Mateer (eds).*Bulletin of the Geological Institutions of the University of Uppsala*, N.S., Vol. 11, pp. 1-24.

MATTHEW, W.D., 1915. Climate and Evolution. *Annals of the New York Academy of Sciences XXIV*, 171-318.

OSBORN, H.F.,1910. *The Age of Mammals in Europe, Asia and North America*. The Macmillan Company, New York.

PETITJEAN, P., JAMI, C. & MOULIN, A.-M., 1992. *Science and Empires – Historical Studies about Scientific Development and European Expansion.* Kluwer Academic Publishers, Dordrecht, Netherlands.

POLANCO, X., 1992. World-science: How is the history of world-science to be written? *In* Petitjean, P., Jami, C. & Moulin, A.-M (Eds). *Science and Empires – Historical Studies About Scientific Development and European Expansion.* Kluwer Academic Publishers, Dordrecht, Netherlands, pp. 225 – 242.

RAINGER, R., 1991. *An Agenda for Antiquity – Henry Fairfield Osborn and Vertebrate Paleontology at the American Museum of Natural History, 1890 – 1935.* The University of Alabama Press, Tuscaloosa and London.

SAID, E.W., 1978. *Orientalism – Western Conceptions of the Orient.* Penguin Books.

SCHLOSSER, M., 1903. Die fossilen Saugethiere Chinas nebst einer Odontographie der recenten Antilopen. *Abhandlungen bayer Akademie der Wissenschaften 22,* 1-221.

SPEAIGHT, P., 1967. *Teilhard de Chardin – A Biography.* Collins, London.

SPENCE, J., 1990. *The Search for Modern China.* W.W. Norton & Co, New York.

TEILHARD DE CHARDIN, P., 1963. *Letters From a Traveller 1923 – 1955.* Collins Fontana Books, London.

THACKRAY, A. (Ed.), 1995. Constructing Knowledge in the History of Science. *Osiris* Vol. 10, The University of Chicago Press.

WADE-CHAMBERS, D., 1987. Period and process in colonial and national science. *In* Reingold, N. and Rothenberg, M. (Eds): *Scientific Colonialism - A Cross-cultural Comparison,* Smithsonian Institution Press, Washington, D.C and London, pp. 297-321.

YANG, J.Y., 1991. The transference of modern geology to China (1840-1937) with a discussion of Basalla's model. *In* Wang, H.Z., Yang, G.R. and Yang , Y.Y. (Eds): *Interchange of Geoscience Ideas Between the East and the West,* China University of Geosciences Press, Wuhan, China, pp. 31-38.