THE NEW ERA IN THE PALEONTOLOGY OF VERTEBRATES

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The paleontology of vertebrates, in particular of mammals, represents the most interesting chapter in the science of fossils. The skeleton of these animals bears the signs of the structure of their bodies to a much greater degree than the skeleton of other types. Therefore their paleontological remains (which represent almost exclusively only skeletal parts) make an authentic construction of their history possible.

Nevertheless, regardless of the presence of very rich localities of vertebrate remains, especially in North America, this history still has enormous problems: thus, up to the present time the origin of many groups has remained unexplained, because the sudden appearance of relatively highly organized and already very diverse mammals, between the Mesozoic and the Cenozoic, and simultaneously in Europe and both Americas, is obscure.

To be sure, certain localities have not been, by far, exhausted. They are contributing and they will contribute for a long time yet separate new forms, which however, will only complement the picture already known, but they will never solve the problems set. Evidently the "centers of development" were situated somewhere in other regions. We should expect to find them anywhere in the regions of less explored countries, for instance in Africa or Asia.

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* Original citation: Borissiak, A. A. 1925. [In Russian.] *Priroda* 1925(4-6):33-76. Translator unknown. Generously donated by the Biosciences Library, University of California, Berkeley, and courtesy of Patricia Holroyd and William Clemens. From *A. A. Borissiak Collected Papers,* UCB call number QE 702 B6. Transferred to electronic copy and edited by Mark Uhen and Michell Kwon, Smithsonian Institution, 2007.

Actually, a few accidental finds contributed materials that uncovered new hopes in this regard. Thus, in the beginning of this century the English paleontologist Andrews, who traveled to Egypt on account of his poor health, accidentally discovered locations of Tertiary vertebrates, working out of which gave highly interesting results. The remains found here permitted a reconstruction of the history of a few groups of mammals, among them two most peculiar: on one side, elephants, on the other *whales*, which are even more peculiarly differentiated. The latest representatives of these groups have departed much from the normal type of mammals, according to their structure. In the Lower Tertiary deposits in Egypt their oldest forms were found, which connect them with the "normal" mammals. Beside that here were found also animals that were not found anywhere else. Consequently, North Africa in the beginning of the Tertiary Period actually represented a special center of development of vertebrates, where some groups, which were later diffused in other regions, had their origin. Elephants, for instance, migrated to Europe and Asia only in the middle of the Tertiary Period, and in North America they appeared even later.

Thus, if Africa gives hope of illumination of some unsolved problems of the history of vertebrates, we can expect much more from Asia. In fact, Asia was dry land of enormous diversions from the end of the Paleozoic Era: those [Mesozoic] sea transgressions, which in large extensions covered, sometimes entirely, other continents, did not touch the central parts of Asia, which remained invariably dry land. On this continent enormous deposits accumulated, forming the so-called *Angarsk/Angara series*. There is all reason to believe that in the deposits of this series are preserved remains of terrestrial faunas, as they changed places one after another in succession.

As mentioned, the unusually interesting find in Northern Africa was made *accidentally*. However this region especially, as well as the more distant parts of Africa and Asia, can by no means be considered geologically unexplored regions, although they have been studied much less than Europe and North America. Why then are such important finds unexpected, and why in general are we obliged to speak of those regions almost as a *tabula rasa* in paleontological respects?

Here we are obliged to stop at a "blank place" in the paleontological chronicle, which is usually not mentioned in the textbooks of geology. It is conditioned by the fact that the paleontologist, up to the present time, has been using in a considerable degree only that material that he was given by the geologist. The latter is far from being impartial toward all strata of the Earth's crust. The fact is that the mass of marine sedimentary formations serves almost exclusively as a scale of the geological periods. The continental sediments, i.e. sediments deposited on the dry land, are to him of much smaller interest. This is explained very simply by the fact that marine deposits are preserved in the mass of the Earth much more fully than the terrestrial. Only from the latest epochs in Earth history we do have a slightly complete series of continental deposits. On the other side, animal remains, which are so important for a geologist in his determination of the age, are much more seldom preserved in the terrestrial mass than in the marine. That is why the geologist grew used to giving his attention predominantly to marine deposits, especially in a new and little explored region, when he necessarily endeavors to gather the most important (from his point of view) data as a general characteristic of the geology of a region. Only most recently, in regions of the best-studied countries (Europe, North America) where the "history of the sea" can be

considered as already more or less explained, the study of the "history of dry land" has begun. That is why the "Angarsk series" which has been known well and for a long time – namely, because it is known as a continental mass – remained little studied up to very recent times. To be sure, the geologist more than once interpreted the levels formed by it, but the Asiatic geologist walks in general in seven-mile boots through deserts, through mountain ridges, and the continental mass attracts his attention only when its separate layers, over-filled with plant remains as it were, of themselves place into his hands "guiding" forms. Thus the lower parts of the Angarsk suite, of the end of the Paleozoic Era, and also those belonging to the Jurassic Period have been "elucidated" long ago. Its entire remaining part, which has been deposited here up to the present epoch, being "mute" (empty), i.e. one not containing paleontological remains, did not draw the attention of the geologist. Some called it the "Gobi" suite others call it "Khanklai" suite, but they traveled fast through the plains formed by it, aspiring to those mountain ridges in which there was hope to find the sea layers with marine faunas. Only once a Russian geologist succeeded in seeing in the "Gobi" layers' remains of vertebrate fossils. He collected several teeth, but the caravan hurried on and the largest discoveries escaped us. These teeth were then identified by a German scholar, who found that they belonged to a Tertiary rhinoceros.

In the meantime, from times immemorial at Chinese markets were sold "dragon teeth", which were obtained from the ground, and which were ground according to the precepts of Chinese medicine and served as medicinal means against various diseases. Travelers bought them or imported them into Europe, and not only the teeth of mammals but also other fossils (trilobites and the like), which thus gave first suggestion to the

geological structure of China. In part, the teeth of mammals obtained in such a manner served for two German monographs, which dealt for the first time with the terrestrial fossils of the faunas of Central Asia. By the pieces of matrix stuck to the teeth it was possible to form an idea even of the deposits in which they were contained.

The first locations of mammals in the continental mass of Central Asia were discovered in the extreme western boundary of its expansion, in the Turgai region. Here in 1912 were found two quite rich ossiferous horizons, belonging to Oligocene and Miocene times, and besides that there were found marks of a younger third fauna (with *Hipparion*). The two lower horizons were worked in the course of several years by the Geological Museum of the Russian Academy of Sciences and they gave abundant paleontological material. Especially interesting remains were given by the lowest (Oligocene) horizon, which was called the Indricotheria layer, on the basis of remains of the gigantic extinct rhinoceroses *Indricotherium* contained within it.

Later in the same mass, but on its opposite limit of expansion, in the Amur region in the older [Cretaceous] layers remains of Dinosauria (*Trachodon*) were found, of a type that up to that time were known only in North America. In the very latest years in the same mass there were discovered bones of Dinosauria in Turkestan.

After the first finds mentioned in the regions of our country, the search for locations of “dragon teeth” began also in the regions of China. Namely, Swedish scientists, taking upon themselves the organization of geological surveys of China, formed a special committee for that purpose in Sweden, and then they promoted the formation of a geological institution in Peking – and with the year 1917 they began to investigate localities of mammal remains in northern China and partly in Mongolia. In a

short time they collected rich fauna, predominantly from the upper Tertiary deposits (*Hipparion* fauna) but they also made finds in both older and in younger strata.

In 1922 the expedition of the American Museum of Natural History (in New York) made even more interesting discoveries in the same continental mass of Central Asia, but this time in the regions of Mongolia. Essentially, it is quite natural the main success in the study of the paleontology of the "Angarsk suite" fell to Americans. In North America, earlier than in other countries, paleontology took the path of independent search of materials, and a push for that was the discovery of localities exclusive in richness of vertebrate remains at about the middle of the last century. Especially beginning with the seventies, American paleontological expeditions took grand dimensions – they enriched the history of vertebrates by colossal new materials, which for the first time enabled the paleontologist to aspire to participation in the solution of general biological problems. These expeditions created special "fossil hunters" who specialized in the search for new localities, and who worked out technical methods for treatment of localities, transportation of the acquired material and its further treatment in preparation – workshops. Those wide tasks, which American paleontologists set for themselves, and great material means which are at the disposition of American museums, allowed the latter to organize expeditions in all parts of the world. One such expedition was that Mongolian Expedition of the New York Museum, which will be referred to further on. Moreover, this expedition, which is called by the Americans the Third Asiatic Expedition (the First and Second Asiatic Expeditions of the New York Museum had a narrower, purely zoological purpose), was originally assigned to collecting fossil remains exclusively. Its aim was the study of geology, botany, zoology, and anthropology. But the

discoveries that were made at first in Mongolia made it almost exclusively paleontological. According to the statement of the head of the expedition, zoologist R. C. Andrews, the conditions indicated, as it were, a new era in the investigation of little-known regions, when all the specialists that participated in this investigation concentrated on one theme, and the theme of the Third Asiatic Expedition became to endeavor "to confirm the theory of a Central Asiatic origin of mammals."

This theory, which has been energetically developed by the head of contemporary American paleontologists, Osborn, who at that time was the president of the New York Museum, and on the other side the supposition that Asia is the center of the development of man, served as a means of propaganda to arouse among Americans a wide interest for the proposed expedition and to collect the necessary means for it. The expedition was calculated for five years, from 1921 to 1926. But already in 1919, its future director, zoologist Andrews, traveled through Mongolia making preparations for future investigations. Among other things he indicated the possibility of a new method of investigation of the central part, which accelerated the work ten times – namely, he decided to substitute caravans of camels, the usual method of communication in that country, by automobiles of a light type. The year 1921 was spent in organizing the expedition at the place. In 1922 the expedition was organized[1] and left Kalgan in April.

It covered 3,000 miles in five months in the above-mentioned manner. Right from the first days, the paleontologists of the expedition began to make one after another ever more sensational finds. Thus, on the third day of their journey (on April 23), bones of the

[1] The expedition consisted of eight Americans beside the chief zoologist Andrews: Granger – chief paleontologist, Berkeley – chief geologist, Morris – his assistant and topographist. Granger had three "fossil hunters" – Kaisen, Olsen, and Johnson; further a driver and a photographer. Besides that it had 8 Chinese and 9 Mongolians. The expedition had 9 automobiles and a camel caravan of 75 heads for transportation of goods.

gigantic rhinoceros *Baluchitherium* were found. In three more days, a rich fauna of Titanotheria was found, and so on. Altogether, in the first year of work in the "mute" Gobi mass, the expedition discovered *eleven ossiferous suites*, belonging to various periods. The following year, 1923, was spent in the treatment of the five richest locations discovered in the preceding year. Besides, there was discovered one more ossiferous suite, the 12th. The results of these works, in as much as the collected materials have been already worked out, will be mentioned further on.

To be sure, the Chinese Geological Institution, which has been mentioned above, was of help to the expedition, because a basis for its work had also been prepared by the Swedes. And from the beginning the Americans went into cooperation with the Swedish and Chinese geologists. Working with them in parallel, the Americans helped them with their technical equipment, while from the local geologists they obtained important information regarding the working conditions. The geological conditions under which the mentioned paleontological finds were made through the works of the expedition of 1922 are described as follows: The Gobi Desert, the main region of investigations, represents one of the largest desert basins, in which Central Asia abounds. Actually this desert is composed of a series of small basins, divided by ridges of low hills. From these hills issue different suites of older matrices that stretch under the newest deposits with which the basins are filled. The old matrices mentioned testify to the complex geological history of the country, but we shall not dwell on it and will turn only to the last chapter of this history when the once mountainous country, composed of marine deposits, became peneplanized[1] and was no longer covered by the sea. The consequent rises and falls of its separate parts, sometimes attended by volcanic activity, conditioned the formation of the

[1] Leveled to almost a plain by the processes of erosion.

basins mentioned. In them deposits were leveled, and tuffogenic matrices were deposited (products of eruption). In short, beginning with the Mezozoic[2] up to now, continental deposits accumulated over the course of a long time. This mass is in places dissected by old valleys, in the slopes of which are beautiful denudations, and it contains a series of ossiferous suites accumulating the remains of those successive faunas that developed and took place one after another on this largest continent, which remained dry in the course of the entire period mentioned. The discoveries of the Americans speak just about this dry land about this "new" continent.[1]

As has been already mentioned, they discovered twelve successive ossiferous suites[2] of which *four* belong to the Cretaceous Period, *seven* to the Tertiary, and *one* to the Quaternary.

We shall consider in short each one of them in as much as the collected materials have been already worked out and permit explanation. Besides, it is necessary to keep in view the fact that the interest of the Mongolian finds is enlarged by the fact that *many "zones" with Mongolian fossils do not coincide with already-known* zones of North America and Europe, but they produce intermediary and consequently entirely new material.

1. Thus, the oldest ossiferous suite (Oshile) contains the remains of the oldest terrestrial *Dinosauria the like of which have not been known* up to this time. From it have so far been described small herbivorous Dinosauria (*Psittacosaurus mongoliensis*) with a

[2] In places – from the end of Paleozoic.

[1] The Americans working about the "new" continent actually "discovered America", because the existence of this continent was known before then. Of course their merits are enormous, they discovered the faunas inhabiting it.

[2] It is possible that the number of these suites will be reduced in time, when it is proven that some of them are contemporary, and that they represent only different facies of deposition. Such supposition is suggested by the comparison of described faunas with the Turgai find, where in our suite are united representatives of two or three Mongolian suites.

beak as in a parrot and with an embryonic shield, and others, *Protiguanodon*, as the name indicates, ancestors of later large iguanodonts, which ran on hind legs. Finally there are also remains of large amphibious Dinosauria, known from the Jurassic deposits. In the seam of thin clays of the same mass there are found remains of insects. This mass can be assigned to the end of the Jurassic or rather to the beginning of the Cretaceous Period.

2. The second location (Ondai Sair) represents the same deposits that settled in a wet climate, with remains of *Protiguanodon*; above them are clays with insects and fishes deposited at the bottom of lakes.

3. The third series of deposits (Djadochta) according to their fauna do not have an analogous state among deposits of other continents. This is henceforth the classical locality of dinosaurs, among which the greatest quantity of remains belongs to the herbivores *Protoceratops andrewsi* – with a sharp mouth with a wide bony frill covering the neck, and with rudimentary horns – the ancestor of the gigantic horned ceratopsids. A whole series of skeletons of these animals is known, beginning with the smallest, which had not yet hatched from the egg, and ending with the fully grown. Here the quantity of the material collected can be judged by the fact that of this form there are 71 crania alone. One of sensational finds of Americans is the *eggs of dinosaurs*. Of these seven complete heaps have been found – some undoubtedly were *in situ*, i.e. they represented nests of dinosaurs – and on one such nest there was found a small predatory dinosaur – an egg-eater, bird-like with a toothless beak, *Fenestrosaurus philoceratops*. There were found also other predatory dinosaurs – also bird-like, but the large-toothed *Ornithoides oshiensis* and the little quick-footed *Ovoraptor djadochtai*. All these forms are new, previously unknown ancestors of certain later groups of dinosaurs. The matrix in which

they were found, red sands, deposited partly in small lakes and partly on land, testifies to a change of regime, an approach of a drier and hotter climate than in the preceding epoch. The period of its deposit is the beginning of the Upper Cretaceous Epoch.

4. The next stage in time belonging to the same epoch, consists of layers (Iren Dabasu) that contain dinosaurs as yet not studied more closely, and belonging to three families: the above-mentioned herbivorous Iguanodontidae, predatory theropods, and ostrich-like Ornithomimidae. At this time dinosaurs had already attained the height of their development and migrated to west and east to Europe to North America, and various groups moved in various direction – hence the difference in the faunas of this period of the Old and New Worlds. After this dinosaurs quickly became extinct, giving place to mammals.

5. Immediately above the strata with the just-described fauna there follow brown and red sandy clays (Gashato) with remains of mammals of an archaic type, mainly in the form of very small jaws (1-4 inches in length). These deposits belong to the end of the Cretaceous Period or the very beginning of the Tertiary. The remains contained in them probably belong to the *so long-awaited first mammals*. As it has been mentioned, mammals appear in Europe and America immediately in better-differentiated forms.

6. On the enormous expanse, forming wide plains, the upper Eocene layers (Arshanto-Irdin Manha) extend with a very rich fauna of mammals, related to the contemporary fauna of North America. Here are found primitive Insectivora, ungulates, and Carnivora. Of the latter attention is drawn by a large form, called in honor of the head of the expedition *Andrewsarchus*. Here were also found numerous small

Titanotheria and teeth of *Loxolophodon*, one of the gigantic representatives of ancient ungulates (Amblypoda).

7. The next locality belongs likewise to the upper Eocene or the lower Oligocene. These are sandstones and clays (Shara Murun) with numerous remains of Titanotheria partly resembling the American long-legged rhinoceroses (*Protitanotherium*).

8. To the lower Oligocene belong sands and clays, sometimes pebbles (Ardyn Obo), with a fauna that suggests the contemporary European fauna (from the Phosphorites of Quercy). Thus here was found *Cadurcotherium* (amphibious rhinoceros), *Schizotherium* (a digging ungulate), a small rhinoceros *Ardynia*,[1] predatory animals (*Cynodictis*), a primitive stag (*Eumeryx*), testifying that this family had its origin also in Asia, and so on.

9. Layers (Hsanda Gol and Houldjin) lying above and perhaps contemporary with the preceding contain a very rich fauna that cannot be younger than middle Oligocene: this fauna is remarkable by its great quantity and diversity of rodents (a thousand separate jaws, but also complete skeletons) and small predatory animals, all mainly *entirely new forms* (even genera).[1] There are very few ungulates, but among them the gigantic *Baluchitherium* is very close to if not identical with the Turgai *Indricotherium*. There are also primitive stags here, mentioned above.

10. The next stage in the development of faunas is represented by the suite (Loh) with mastodonts, appearing here for the first time, and rhinoceroses. This suite already belongs to the Miocene, and apparently corresponds to the Djalanchik strata of the Turgai region.

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[1] The last two forms have, if not identical, then very close representatives in the Turgai fauna.
[1] Predators representing an intermediate stage between the old Miacidae and later civets, Canidae, etc.

11. Then follows an even younger Pliocene fauna (Hung Kureh), relatively poor, represented by small stags, antelopes, horses (three-toed), a camel, an elephant, a beaver, and so on.

12. And, finally, there follows the youngest Quaternary fauna (Olan Diske) with the mammoth and rhinoceros.

As has been mentioned, the year 1923 was spent in working out of some of the locations (namely, Nos. 3, 4, 6, 7, and 8). The interest, aroused by these finds, was so great, that toward the end of the summer the venerable president, Prof. Osborn, came personally to inspect the results of the expeditions of his museum. He barely escaped death in Peking at the time of the famous great earthquake in Japan. In the course of several days he visited the most important excavations, and then it was admitted at the meeting of the scientists of the Expedition that the period assigned earlier, in view of these unexpected discoveries, which were promising enormous material, was too short for field works, much more so because it was proposed to go on to Tibet and Chinese Turkestan. It was decided to stop the work, to send everything that had been collected to New York to give accounts, publish them, and together with that to decide on the plan of future work.

On the way back, the expedition, getting ready to sail for America, spent about three weeks in Peking and, one can say, all this time was a continuous ovation to the American discoveries. In honor of the Americans banquets were given almost every day by various organizations, beginning from the select society of the American and English colonies and ending with the Chinese students Cady. This gave Osborn occasion to give a series of talks of which the first was naturally addressed to press representatives. It lasted

three hours, and as a result telegraphs were sent all over the world announcing the successes of the American science. Osborn exposed the scientific side of the work before the Chinese Geological Institution, which elected him for its first honorary member. At the banquet given by the American Association of North China, he spoke about the "conquests of American science" to the students about the "observation and discovery"; in the Society of Friends of literature, which consists of the cream of international "intelligentsia" in Peking—"why couldn't Mongolia be the cradle of human race." To the wide Chinese public he spoke "on the origin of man." In the university he spoke "on evolution and religion," and so forth.

When the material collected was sent to America, immediately the energetic working out of it began. In this work took part, of paleontologists, Osborn, Matthew, Granger, and Gregory. Besides a whole series of popular articles dedicated to this expedition, already 22 preliminary scientific descriptions appeared,[1] of which the majority are dedicated to paleontology. The results attained have been given above in the shortest way in the characterization of individual localities. For the future is planned an edition of a capital, all-embracing description of scientific results of the expedition, under the common title "Mongolia" in 12 volumes.

As for further works, it was decided to extend the time of the "Third Expedition" by three years against the earlier-proposed time (i.e. to 1928). Work will begin from Chang-Nor (1,000 miles from Kalgan) from the point where it was stopped in 1923, and will proceed to the north and south. If in 1923 main attention was given to older strata with reptiles and mammals, now special attention will be given to younger Tertiary strata.

[1] The volumes, containing a general description of the course to the topography and geology of Mongolia, are already being prepared for the press. Beside this a popular edition in 2-3 volumes has been proposed.

Besides the remains of mammals, the expedition hopes this time to be luckier in its search for the oldest remains of man. It was likewise decided to increase the scientific staff by including an archaeologist (Nelson), a paleobotanist (Chancy), an anthropologist, and an ornithologist. In order to organize this trip to Mongolia, Andrews went already in June 1924 to Urga, where he had prepared a new caravan of 200 camels, which was sent early to the place of works, and in February 1925 the entire scientific staff of the expedition left New York.

It is interesting to remark that almost the entire money necessary for this expedition (500,000 dollars a year) was collected by Andrews by subscription: in this subscription more than 200 persons participated from all parts of the U.S.A. (from 23 states). Thus these contributions assured the expedition for all five years of its work. It must be admitted that here the gold found its most noble use; that gold which had been accumulated by Americans in the European catastrophe.

In one of his speeches Osborn called the Mongolian investigations the discoveries of a new era in the history of vertebrate paleontology. He compared them in significance with those discoveries made in the middle of the last century by Joseph Leidy in the western states of the U.S.A. (see above). The Asiatic continent in the Cretaceous and Tertiary was the center of development of the most important orders of Reptilia and Mammalia. The materials collected there should finally solve those problems of vertebrate history, which up to the present remained unsolved, on the origin of the majority of groups of terrestrial vertebrates and on the development of mammals, the oldest representatives of which have been known to us up to the present only in the form of relatively highly organized forms, which suddenly appeared on the continents of

Europe and North America at the beginning of the Tertiary Period. If these tasks are solved, then the Asiatic material must be given even a greater importance than that which in their time was held by the paleontological investigations of North America. Judging by the fact that of the results of the expedition so far published, of greatest interest are finds giving the oldest dinosaurs, which were unknown up to this time, and for the history of mammals –locality 5, which promises to give up to this time unknown links of their history.[1]

If the materials for the history of man are found – the problems will be solved perhaps next year (see above). In any case, one thing is certain: by enumeration of the above discoveries the last word has not been said on the possibilities of the continental mass of Asia. The discoveries described were made in the mass that was up to that time considered "mute" by a whole series of investigators. They were made thanks to a long experience, and the vision of American "fossil hunters" sharpened by that experience.

The first discoveries of individual single bones took enormous work, and only the excavations undertaken after that disclosed the richest localities. In this new approach to the collection of fossils, when the paleontologist is not satisfied by the accidental finds of the geologist, and when he himself systematically seeks where he believes to get results, a new era in the history of science of fossils must be seen.

One more trait in the work of Americans must be mentioned: their friendly cooperation with the Swedish and Chinese Institution that was mentioned above. We are not accustomed to such a gentlemanly relationship in Europe. They set an example for other investigations that worked and are working in the same faunas in Asia. Upon their

[1] For instance, ungulates in Europe and the New World appear already with the limb reduced to four toes. Osborn hopes to find their five-toed ancestor in Asia. There are similar expectations for other groups also.

return to New York they immediately began a correspondence with them, with the aim of securing their priority in scientific work. Their considerate attitude toward modest Russian work must be especially mentioned, which appeared (thanks to lucky finds in the Amur and Turgai regions) at the dawn of the “new era,” and in the words of Americans, paving the road for their much greater work.