7th, 1881, the honour of Knighthood was conferred upon him in acknowledgment of his long and distinguished public services, and at the end of the year Sir Andrew Ramsay resigned his appointment as Director-General of the Geological Survey of the United Kingdom.

The present Director-General of the Geological Survey, A. Geikie, Esq., LL.D., F.R.S., has been connected with that service since Oct. 15, 1855. When the Geological Survey of Scotland was recognized as a separate branch of the establishment, Mr. Geikie was appointed as Director. In 1865, Mr. Geikie was elected a Fellow of the Royal Society of London; he was President of the Geological Section of the British Association at Dundee in 1867, and again at Edinburgh in 1871; in the same year he was created Murchison Professor at the express wish of the founder of the Chair, an appointment which he only recently resigned. In 1873, the University of Edinburgh conferred upon him the distinction of LL.D., and in 1881, the Geological Society, in recognition of his scientific labours, presented him with the Murchison Medal. Mr. Geikie is well known as an accomplished writer. Amongst his many contributions to geological literature may be mentioned, "The Story of a Boulder," 1858; "The Glacial Drift of Scotland," 1863; "The Scenery and Geology of Scotland," 1865; this was accompanied by a Geological Map of Scotland; "The Life of Murchison," 2 vols. 1874; and his lately published "Geological Sketches at Home and Abroad." He contributed the exhaustive article on Geology to the current edition of the Encyclopædia Britannica, and is now engaged in the preparation of a "Text-book of Geology," which will form a volume of some 800 pages.

II.—On the Mode of Origin of the Loess.

By Professor Baron F. Richthofen,
of the University of Bonn-on-the-Rhine.

[THE following communication, although addressed to the Editor in the form of a letter, is of such importance that we need make no apology for treating it as an Original Article, feeling sure that our readers will be as much interested as ourselves in the observations of so eminent a geologist, who has spent many years in actual study of these vast deposits, as to the origin of which he is consequently able to speak with such profound knowledge and mature judgment. —Edit. Geol. Mag.]

Sir,—You will receive in a few days a copy of the second volume of my work on China, which I requested my publisher (Mr. Dietrich Reimer, of Berlin) to send to your address.[1] In this volume are embodied the results of my travels in *Northern* China, and it is chiefly devoted to the geology of that country. The third volume will comprise Southern China, while the fourth, which is to contain the description of a portion of the fossils collected by me, is now going through the press and will be ready within a few months. It will be accompanied by 52 plates. The palæontological memoirs

[1] Since received.—Edit. Geol. Mag.

in it have been prepared by Messrs. Dames, Kayser, Lindström, Schenk and Schwager. Unfortunately, the topographical and geological maps relating to Northern China (14 sheets), which will be published as the first portion of an Atlas of China, are not yet ready, and the second volume, to which this first series of maps belongs, must make its way for some time without their aid.

I hope that, if you should consider the book worthy of a special notice in the MAGAZINE, the reviewer will kindly take into consideration that, with the exception of the very able report of Pumpelly on a district of comparatively small extent in the vicinity of Peking, this is the first attempt towards the geological description of a vast region which, orographically as well as geologically, was entered by me as a *terra incognita*, and that as a solitary wanderer I did not enjoy the advantages offered to the geological member of a well-equipped expedition, who can devote all his energy to one single class of subjects, and is neither occupied with the construction of his own topographical maps, nor hampered by the daily-recurring care of pack-mules, carriage-bearers, etc.

The first volume of my work, which was published in 1877, has not been sent to the GEOLOGICAL MAGAZINE, because its contents were chiefly geographical and historical. One geological problem only was treated in it at considerable length; this is, the origin of the Loess and the mode of growth of the soil of steppes. It appears to me, therefore, quite natural that the book should have been taken notice of by only a few geologists. But I might have expected that a prominent scholar, who in his literary studies has moved over the same ground with me and, although with a far wider scope of learning than I acquired and at very much greater length than I was able to devote to the subject, has treated the history of Central Asia, should have at least glanced at the contents of the book. Such, however, has evidently not been done by Mr. H. H. Howorth, when he undertook to discuss the question of the origin of the Loess in two numbers of the MAGAZINE (January and February, 1882), and it appears that my publications on the subject have completely escaped his knowledge. All he knows respecting a theory on the mode of origin of the Chinese Loess, which I first advanced in 1870, is taken from the few lines of a foot-note of a paper by Mr. Kingsmill, who, in 1871, accepting the name of Loess, which I applied to the Chinese deposits, suggested a theory of a marine origin for them (Quart. Journ. Geol. Soc. vol. xxvii. pp. 376 to 383).[1] If the words in which Mr. Howorth mentions my theory did really render it, his

[1] The theory of the subaërial origin of the Loess, which, according to Mr. Howorth (p. 16), "has received the sanction of Richthofen and Pumpelly," but which, in fact, was started by me and endorsed by M. Raph. Pumpelly (*N. Y. Nation*, April 14, 1878), who had advocated before a fluviatile origin, was noticed first very briefly in my *Letter on the provinces of Honan and Shansi*, Shanghai, 1870, pp. 9-10, and at some greater length in my *Letter on the provinces of Chili, Shansi, Shensi*, etc., Shanghai, 1872, p. 13-18. The full discussion of the subject is given in *China*, vol. i. pp. 56 to 189, and a short abstract in *Verhandlungen der K. K. geologischen Reichsanstalt*, 1878, pp. 289 to 296. I could not avoid reverting to it repeatedly in *China*, vol. ii. (see for descriptions f. i. pp. 349-351, 422-427, 530-533, 550-551, and for discussion, pp. 741 to 766).

arguments against it would, at least in part, be well founded; but I consider it not improbable that he would not have started the controversy if he had taken the trouble to make himself acquainted with the subject against which it is directed.

Will you allow me, therefore, to offer to the readers of Mr. Howorth's article a short explanation of the views at which I arrived regarding the mode of origin of the Loess when I was gazing daily at its astounding deposits and grotesque features in the Chinese provinces of Honan and Shansi, views which I found not only corroborated during my further travels throughout all Northern China and in the Mongolian Steppes, but which, on the strength of comparative study, I was afterwards able to apply with equal force to Tibet, the region of Khotan and Yarkand, and great portions of south-western Asia, as well as to all Loess-covered regions of Europe, and of the continents of North and South America.

Any theory which undertakes to deal with the problem of the origin of the Loess must give a valid explanation of the following characteristic peculiarities of it, viz.:

1st. The petrographical, stratigraphical, and faunistic difference of the Loess from all accumulations of inorganic matter which have been deposited previously and subsequently to its formation, and are preserved to this day.

2nd. The nearly perfect homogeneousness of composition and structure, which the Loess preserves throughout all the regions in which it is found on the continents of Europe and Asia; it offers in this respect a remarkable contrast to all sediments proved to be deposited from water within the last geological epochs, excepting those of the deep sea, which are here out of the question.

3rd. The independence of the distribution of the Loess from the amount of altitude above sea-level. In China it ranges from a few feet to about 8000 feet above the sea,[1] and farther west it rises probably to much greater altitudes. In Europe it is known at all elevations up to about 5000 feet, at which it occurs in the Carpathians.

4th. The peculiar shape of every large body of Loess, as it is recognized where erosion has cut gorges through it down to the underlying ground without obliterating the original features of the deposit. These are different according to the hilly or level character of the subjacent ground. In hilly regions the Loess, if little developed, fills up depressions between every pair of lower ridges, and in each of them presents a concave surface; but where it attains greater thickness, it spreads over the lower hills, and conceals the inequalities of the ground. Its concave surface extends then over the entire area separating two higher ranges, in such a manner as to make the line of profile resemble the curve that would be produced by a rope stretched loosely between the two ranges.

[1] I met with it in China, in 1870, only at an altitude of 6000 feet, and this figure is given by Mr. Howorth (p. 76) erroneously as an observation of Mr. Kingsmill; in 1871 I found thick deposits of Loess at an elevation of 7000 feet in Southern Mongolia, and of 8000 feet on the Wu-tai-shan range in the province of Shansi.

This shape of surface is precisely similar to that which is characteristic of the salt steppes of Central Asia. It must, however, be remarked that, just as in these, the development is frequently unequal on either side of a valley, and that the preponderance of the deposit on the same (f. i. the westerly) side can sometimes be observed in each basin throughout a larger region. The lowest portion of the surface of larger basins is frequently taken up by stratified soil consisting of the finest particles of Loess, and exhibiting a strong impregnation with alkaline salts. Over table lands and plains Loess is spread in the shape of most uniform sheets.

5th. The composition of pure Loess, which is the same from whatever region specimens may be taken, extremely fine particles of hydrated silicate of alumina being the largely prevailing ingredient, while there is always present an admixture of small grains of quartz and fine laminæ of mica. It contains, besides, carbonate of lime, the segregation of which gives origin to the well-known concretions common to all deposits of Loess, and is always impregnated with alkaline salts. A yellow colouring matter caused by a ferruginous substance is never wanting.

6th. The almost exclusive occurrence of *angular* grains of quartz in the pure kinds of Loess.

7th. The complete absence of stratification. To this must be added the singular position of the laminæ of mica. When these are deposited by water, they are arranged horizontally and accumulated in separate layers, while in Loess they are distributed without any order, and occur in every possible position.

8th. The capillary structure caused by the occurrence of innumerable tubes, mostly incrustated with carbonate of lime, which have generally a vertical position, and ramify downwards like the roots of grass. Where Loess is covered by vegetation, the tubes may be seen taken up by rootlets to the depth of a foot or a few feet from the surface. In this internal structure, besides the mode of occurrence, is founded the chief difference of Loess from ordinary loam. The former may be designated as a kind of calcareous loam provided with internal structure.

9th. The tendency to vertical cleavage, which is the immediate consequence of the two last-named properties.

10th. The fact that land shells are imbedded in immense numbers throughout the Loess, and that the most delicate shells are perfectly preserved. Fresh-water shells are of extremely rare occurrence, as has been correctly pointed out by Mr. Howorth.

11th. The great quantity of bones of mammals found in the Loess, the genera and mostly the species, or the next relatives, of which are known to abound at present in steppes and on grassy plains. Herbivorous animals are represented as well as carnivorous preying on the former.

12th. The fact that wherever Loess fills a basin between hills, the inclined slopes of these are covered by angular fragments of the adjoining rock, on which the yellow soil rests. Layers of these fragments, beginning with a slight inclination and then passing into

an horizontal position, extend from the hill-sides for some distance into the accumulation of the Loess itself, separating it in the neighbourhood of the encasing slopes into layers of varying thickness, while towards the central portion of each large basin this separation ceases almost completely, and the soil is very homogeneous from top to bottom, even in those instances where the vertical thickness is 1500 feet and more.

It is perfectly evident that no theory starting from the hypothesis of the deposition of Loess by water can explain all or any single one of these properties. Neither the sea nor lakes nor rivers could deposit it in altitudes of 8000 feet on hill-sides. Origin from water is perfectly unable to explain the lack of stratification, the profuse existence of capillary tubes, the vertical cleavage, the promiscuous occurrence of grains of quartz, the angular shape of these, the confused position of the laminæ of mica, the imbedding of land shells, and of bones of terrestrial mammals.

There is but one great class of agencies which can be called in aid for explaining the covering of hundreds of thousands of square miles, in little interrupted continuity, and almost irrespective of altitude, with a perfectly homogeneous soil. It is those which are founded in the energy of the motions of the atmospheric ocean which bathes alike plains and hill-tops. Too little weight has been granted hitherto by geologists to these agencies, and yet there is no other which has contributed in a greater measure to determine and to modify the character of the surface of any portion of the ground after its emergence from the sea, and to predestinate wide regions for the existence of certain kinds of plants and animals, and for the modes of nomadic or agricultural life of mankind.

Wherever dust is carried away by wind from a dry place, and deposited on a spot which is covered by vegetation, it finds a resting-place, and may be washed off and carried farther away by the next rain, if the ground is sloping, or it may be joined to the soil if the ground is flat or slightly inclined. If these depositions are repeated, the soil will gradually grow. At the same depth, therefore, to which the deepest rootlets of the grass of to-day are descending, the soil may have had its surface centuries ago. Remains of the past, such as buildings and entire cities, may in this way have been entombed by dust, provided that plants were growing on its deposits, and could secure a resting-place to all further supplies of atmospheric sediment.

In regions where the rains are equally distributed through the year, little dust is formed, and the rate of growth of the soil covered with vegetation will be exceedingly small. But where a dry season alternates with a rainy season, the amount of dust which is put in motion and distributed through atmospheric agency can reach enormous proportions, as is witnessed by the dust storms which in Central Asia and Northern China eclipse the sun for days in succession. A fine yellow sediment of measurable thickness is deposited after every storm over large extents of country. Where this dust falls on barren ground, it is carried away by the next wind; but where it falls on vegetation, its migration is stopped.

In rainless deserts the wind will gradually remove every particle of fine-grained matter from the soil, though a new supply of this may constantly be provided by the action of sandblast. The sediments of desiccated lakes, the soil which is laid bare by the retiring of the sea, the materials which are carried down by periodical torrents from glaciated regions to desert depressions, the particles which on every free surface of rock are loosened by constant decay—all these will be turned over again and again by the wind, and undergo an incessant sifting, until every earthy grain is blown off and nothing but moving sand and wind-worn pebbles remain.

The dust may travel great distances, and if the wind during the dry portion of the year blows constantly in one direction, that distance will increase, while the deposition of æolian sediments will be cumulative in places situated in the same direction. If the dust is deposited on mountain ranges endowed with considerable fall of rain and drainage towards the sea, it will be finally carried to this reservoir.

There are, however, chiefly two great classes of places where the dust of continents will rest permanently, and continue to accumulate through ages.

The first are what may be termed the central regions of continents, that is, those regions where, notwithstanding some rain which chiefly falls in one season of the year, the water has no drainage towards the sea, but is collected in inland basins from which it evaporates. This is the case in the Great Basin of North America, in Persia, and in Central Asia, from the Pamir to the Khingan range, and from the Himalaya to the Altai. The prevailing vegetation, independently of altitude, is that of the salt steppe. Grass and herbs take hold of the dust, whilst the debris that collects slowly on the hill-sides is, by very slow gradations, washed down the slopes by occasional rains, and will, if there happens to occur a period of heavier rainfall, be spread over a portion of the surface of the steppe, giving rise again to the growth of vegetation, which in its turn takes hold of the falling dust. In this way the dust will accumulate slowly but constantly through ages on those portions of the surface which are covered by vegetation. In the course of time it may reach a thickness of hundreds and perhaps of thousands of feet. The salts resulting from the decomposition of the rocks, and carried partly through the air together with the dust, and partly by water down the hill-sides, will remain in the soil, and collect chiefly in salt pools situated in the lowest portions of each basin, where, at the same time, stratified soil is deposited. As the surface which bears the vegetation is by slow degrees rising to a higher level, the tubes in the soil which contained the roots of former generations will retain their shape. The land-shells which feed on the steppe and withdraw to some depth underneath the surface in seasons of drought or cold will be entombed where they die, and the most delicate shells will be preserved. The same will be the case with the bones of mammals and birds living on the steppe, the dryness of the climate preventing the decay of any organic matter, as well as the formation of vegetable

mould, which would be created in a moist climate through the decay of the organic matter.

In this way the deepest valleys, the wildest gorges, and the largest depressions in undrained regions may be gradually filled up with the deposits of dust, interchanging near the encasing slopes with the angular debris of rocks, but increasing in homogeneousness of composition and structure, and in freedom from any foreign ingredients towards the central portions of each basin. The inequalities of the ground will disappear, the lower hills will be buried, and the surface of the steppe will have a trough-like shape between every two protruding rocky ranges. If then, in consequence of a lasting change of climate, such a basin should gradually be filled with water, and an outward drainage be opened, erosion would soon furrow deep channels through the earthy deposit and expose its interior structure; the fine tubes marking the site of the roots of countless generations of plants, the remains of the shells that had fed on the grass, and the bones of the mammals that have lived on the steppe would become visible; and the earth so exposed would be what is called Loess.

Such was the line of argument which I founded on the study of the Chinese Loess. I concluded that the same regions where the traveller of the present day moves between stupendous walls of yellow earth, and gazes with daily renewed wonder at the fantastic shape of rocks of earth produced by erosion; where millions of people live in caves dug in the vertical faces of the Loess, while on its terraced surface they cultivate fields which are highly productive in wet summers, and terribly barren when moisture is not supplied in sufficient quantity—that these same regions, through which the Yellow River and its tributaries now take their courses, were once covered with dreary steppes only fit for nomadic life, and had no drainage towards the sea.

I had soon an opportunity of verifying the theory by a visit to Mongolia, where I saw precisely what my experience in the Loess regions had caused me to expect, namely, the very same shape of surface which I had observed in these, a steppe vegetation growing upon an impalpably fine earth mixed with grains of sand, and accumulations of the debris of rocks at the foot of the hill-sides. But in no place could I see the inner structure of the soil exposed to view. Proceeding, however, to the boundaries of the undrained region, where the drainage of some marginal basins had begun, but the channels of erosion were still shallow, the first sure signs of true Loess made their appearance on the side of every natural cut in the ground. From this first stage of the conversion of steppe basins into Loess basins, all grades of passage to the wildest and most grotesque landscapes, where the Loess was exposed to view in a thickness of a thousand feet, could be observed in rapid succession.

It appears to me that the theory answers all requirements as regards the Chinese Loess, in so far as it easily explains all its properties and every incident in the mode of its occurrence. It combines, moreover, into one class of natural processes two kinds

of phenomena, which, although they are almost the reverse of each other in regard to their outward appearance and the conditions they afford to human existence, are closely allied in nature in respect to their geographical distribution. It need only be noticed that the salt steppes of Central Asia are surrounded on all sides by Loess regions. The chief difficulty, when the theory was first advanced, was the want of a sufficient source whence the enormous amounts of dust required by it could have had their origin. But the problem has since been resolved in a most ingenious and, as I believe, satisfactory way by Mr. Raphael Pumpelly.[1]

There exist, besides the undrained salt steppe, regions of a somewhat different kind, which serve as permanent resting-places to the subaërially deposited dust. They are sufficiently distinct from the former class of places of deposition to be styled a second class of these, although, as a matter of course, there must be a series of gradations connecting both. To this second class belong those wide grass-covered plains which are known by the names of prairies, savannas, llanos, pampas, steppes of Southern Russia and Siberia, etc. They, too, are subjected to the alternation of a dry and a wet season. They are distinguished from the drainless salt steppe by their level surface and by the fact that they are crossed and partly drained by larger rivers, the origin of which lies almost exclusively beyond their boundaries. Some of these regions are very moist in the wet season, and bear a luxuriant vegetation of grass and flowering herbs, but dry up completely during the rest of the year. The rate at which the growth of soil takes place will depend upon the character of the adjoining regions from which the winds prevailing in the dry season remove the loose soil. It can no longer be doubted that the "black earth" of Southern Russia is growing in this way, and I am inclined to the same opinion with regard to the "Regur" of India. The black colour, which is proper to the uppermost layer only, appears to result solely from the formation of vegetable mould, the deeper portions showing the brown colour of the Loess, together with its structure, although this appears to be less perfect than in the former case. The bones of mammals will probably be badly preserved in this soil, because, in consequence of the ample rains and the slow rate at which the soil grows, they will partly decay before being perfectly covered up. This may not necessarily apply to those land shells, the animals of which die underground, at their places of refuge.

Another difference from the steppes of the first class must be produced by the circumstance that the salts will be removed, in part, by the water which percolates the soil and takes its way to the river channels.

When, after my return to Europe, I commenced to study more closely than I had done in former time the Loess of this continent, its perfect similarity in regard to composition, structure, and mode of occurrence with that of Asia, could not fail to strike me forcibly, and led me irresistibly to the conclusion that it must have been

[1] Amer. Journ. of Science and Arts, vol. xvii. 1879, p. 133.

formed by the same process of long-continued subaërial deposition of dust on steppes as that of the eastern continent, and the arguments which I had applied to this appeared to me to be no less valid for the Loess regions of North and South America.

The Loess-covered portions of Europe extend, as is well known, from the Pyrenees, the Alps, and the Balkan in the south to Belgium, the North German plains and Poland in the north, and from southern France in the west to beyond the limits of the continent in the east. Every portion of this entire region must have had the character of a steppe during a sufficient length of time to allow the deposit to be formed in at least such thickness as we observe at present. This thickness increases on an average as we proceed from north-west to south-east. It appears that, while east of the Alps the beginning of the steppe era may have been of earlier date, it commenced in Galicia, Germany and France during, or shortly after, the time of most extensive glaciation, and that one or the other kind of steppe was formed on the ground of the moraines as they were gradually laid bare by the retiring of the lowland glaciers. When Europe had its north-western limit beyond the present bathymetrical line of one hundred fathoms, and the summit line of the Alps was at greater elevation than at present, a continental climate must have prevailed such as is the prime condition for the formation of steppes, and it is probable that these had then their widest extent in a north-westerly direction. It would lead me too far now to explain why it appears that the conditions of climate, vegetation and animal life prevailing north of the Alps, after having gone through a stage resembling that of the tundras, must have been intermediate in character between those existing at the present time in Siberia and those prevailing in Southern Russia, while various evidence goes to show that farther south-east, in the Hungarian and Roumanian basins, there was no drainage to the sea, and the steppes of these countries resembled those of the drainless regions of Asia.

Gradually, when, with the renewed intrusion of the sea upon the land, the continental climate of Central Europe was converted into an oceanic climate, the change progressing slowly in the direction from north-west to south-east, the growth of the Loess ceased in the north-west, while it still continued in the south-east. Even now the soil is growing where it is covered by vegetation and sheltered from erosion. But the process is extremely slow and, with the exception of Southern Russia, is no longer regional, places of subaërial deposition being scattered among others of erosion.

At the same time when I published these arguments regarding the mode of origin of the Loess of Europe, Dr. Nehring, of Wolfenbüttel, came in the course of his admirable researches on the bones found in the Loess of Northern Germany to the well-known result, that the mammals which lived there at the time of the formation of that earth were identical with, or nearly related to, those which are living now on the steppes of Arctic regions, as well as in Siberia and Central Asia, and he concluded, that Germany must then have

had the character of a steppe, and been subjected to a climate similar to that which prevails at present in western Siberia.

Thus, Dr. Nehring, who, at that time, had no knowledge of my researches, was led through the study of the fossil remains to precisely the same conclusion regarding a limited region in Europe, at which I had arrived with respect to a large portion of the continent by arguing on the structure and mode of occurrence of the Loess. Since then, the continued studies of the bones of mammals contained in the Loess, which have been made by Dr. Nehring and others, have yielded an overwhelming amount of evidence in the same direction, and have enabled us to extend the first conclusions to the whole of Germany, including the Rhine valley, Bohemia, and the vicinity of Vienna, and also to Hungary.

I believe I am correct in stating that, among those who have had extensive experience in Loess regions, all who have pronounced an opinion of late years are agreed that subaërial deposition is the only mode of origin by which all its peculiar features can be easily explained. Besides Mr. Raphael Pumpelly, who knows the Loess of Asia and North America, I mention chiefly Dr. Emil Tietze, of Vienna,[1] who studied it in Persia and Galicia, and the late Professor Karl Peters, of Gratz, who has probably examined a greater extent of European Loess regions than any other geologist, and, like Pumpelly, had, previous to 1877, advocated an aqueous origin as strongly as he afterwards did the subaërial. The celebrated M. von Middendorff has lately changed his views in a similar way.[2]

According to the subaërial theory as here pointed out, two different climatic stages are required for the formation of the typical Loess regions, the first of them marked by a continental and generally dry climate, during which the soil accumulated, the other distinguished by an increase in the fall of rain, in consequence of which the soil was furrowed by the erosive power of water and the steppe basins were converted into Loess basins. It is obvious that the conditions afforded for the existence of plants and animals and for the mode of life of mankind must have been almost the reverse of each other in either of the two stages, and that their change in time corresponded exactly to their change in space, as witnessed at present by the traveller when he descends from the Mongolian salt steppes with their uniform vegetation, their animals peculiarly adapted to a roving kind of life and their nomadic and unagricultural people, to the Loess basins of China, the characteristic feature of which consists in the labyrinthic ramification of very narrow gulches cut in the yellow soil to very

[1] Jahrbuch der K. K. geolog. Reichsanstalt in Wien, 1877, pp. 341-371; and more fully explained in the same journal for 1882, pp. 111-149. This last notice, which is of great importance, came to my knowledge after writing the present article.

[2] Mém. de l'Acad. Imp. des Sc. de St. Pétersbourg, t. xxix. 1881. It appears that Mr. W. T. Blanford has also adopted the theory of the subaërial origin of the deposits filling up undrained inland basins (see Proceed. R. Geogr. Soc. 1881, p. 79), and Mr. Clarence King informs me by letter that he ardently advocates the same mode of origin regarding the Loess regions of the Mississippi basin.

great depth and with perfectly vertical faces. It is this character of surface, together with the fact of the existence of a drainage at low level and the removal, by it, of the soluble salts, which causes the remarkable contrast between the features of Northern China and those of Mongolia. Vegetation offers there a far greater variety of forms; those animals which are accustomed to roving on the boundless steppe cannot exist where the greatest possible unevenness of the soil is the distinctive mark; and man is simply forced to adopt in the Chinese Loess regions a settled and agricultural mode of life, drained Loess being of all kinds of soil best adapted for the cultivation of cereals, while the innumerable recesses and naturally fortified positions afford him shelter and safety.

It seems hardly necessary to observe, how important, on account of this mode of origin, the occurrence of Loess is to the study of the causes of the present distribution of plants and animals. The peculiar climatic conditions prevailing during the time of its accumulation, and the physical features of the regions covered by it must have influenced migration and variation in a considerable measure, and it is far from improbable that the habits of life and the migrations of primitive man over large portions of Europe and Asia have been directed by the same causes. It must be added that a slight deterioration of the climate is sufficient to change the steppe, and chiefly the drainless salt steppe, into the most arid desert, and to cause the emigration of man and animals.

I have given this *exposé* a greater length than I intended. It will refute, without any further discussion, the objections which Mr. Howorth has raised against the theory of the subaërial origin of the Loess, as, *e.g.*: that subaërial deposits such as this are nowhere being formed now (p. 16);—that it is incredible that subaërial deposits should have been deposited at a height of 6000 feet and to the depth of 1000 feet (p. 76);—that the subaërial theory treats the problem as a local Chinese problem, while it ignores that the Loess has to be accounted for in Europe as well as in China (p. 76);—that it cannot be understood how shells and animal debris could be carried by the wind (p. 76);—that the means would be inadequate to the end, as clay would not be acted upon by the wind (p. 77, after Kingsmill);—that the chemical composition of the Loess does not correspond with that of the inorganic elements of plants growing on its surface;—that there is no known means by which these inorganic matters could have been supplied from the atmosphere;—that, although silica might have been conveyed by the medium of dust storms, no way can be seen how the silicate of alumina could be conveyed;—that there is no evidence of the ramifying tubes having their origin in the roots of plants;—that the Loess is devoid of organic substances;—that Loess, if subaërially deposited, should be different in composition according to the subjacent rock and could not be equal everywhere.

After having attempted to set aside, on these grounds, the theory of the subaërial origin of the Loess, which, evidently, was known

to him by name only, but never by the arguments on which it rests, Mr. Howorth proceeds to expose his own hypothesis. Like that of his predecessor Dr. Hibbert Ware, of 1832,[1] it is boldly founded on the supposition of cataclysmic events of tremendous magnitude. But while Dr. Hibbert, who had with regard to the occurrence of the Loess the limited knowledge of his time, was satisfied with one event, namely a great flood, Mr. Howorth, to whom the whole amount of the present knowledge of the subject was accessible, presupposes two stages. The first was marked by a vast volcanic outpouring of "subterranean mud," while in the second this mud was "largely steeped in floods of water," and "mixed with the ingredients of the superficial bed over which it poured." The mud was thereby spread over large extents of country, mammals and shells were imbedded in it, and the entire mass was deposited without stratification, although the flood must have reached up to at least 5000 feet in Central Europe, and to 8000 feet in China, overwhelming, as must be supposed, almost the whole extent of two continents. A similar event should have drowned simultaneously the two American continents and annihilated almost all beings living above the level of the sea. Granted, however, the flood, it is by no means easy to understand its character, as its author is opposed to the aqueous origin of the Loess, whether it be marine, or lacustrine, or fluviatile. It might be supposed that the flood consisted altogether of erupted mud, but we are not told why it did not leave a homogeneous sheet spread over the entire continent up to a few thousand feet, nor how it happened that the deposits we do find from this supposed flood occur in those regions only where the conditions of a continental climate have prevailed and do, in the greatest part, prevail to this day; nor do we learn the reasons why the Loess differs completely in composition and structure from all known kinds of volcanic mud ancient or modern, or how it is that the supposed fissures from which the enormous masses of muddy volcanic rock poured forth were rent at very great distance from the regions of the main distribution of the Loess, and at a time when volcanic energy, which had been most violent in the Tertiary age, was (at least in the regions in question) in its very last and dying stage.

I do not believe that any geologist will seriously take the trouble to argue against these fanciful views. It is strange that the same deposit which bears testimony in itself of having been formed in the slowest, the most quiet and undisturbed manner that can be imagined, should be considered the product of events grander and more violent in character than any heretofore devised in the long history of unfounded geological speculation. Whoever undertakes to advance a theory on a geological subject, should first observe, and observe again, and then compare his own results with what has been observed by others in other parts of the world. If the author of the volcanic theory of the Loess had devoted the same admirable industry, with which he has studied and written the history of the Mongols, to the personal observation of the soil on which the

[1] This theory was noticed in *China*, vol. i. p. 162.

wanderings and warfare of that people did very prevailingly take place, and which from their original seat in Central Asia and their imperial city of Khanbaligh spread to the west of Europe; if he had, besides, taken the trouble to make himself acquainted with the arguments of the existing theories respecting the mode of origin of this soil before undertaking to put them aside; and if he had for a moment considered from a geological point of view a few of the concomitant circumstances required by his own theory, he would hardly have ventured to adopt views which could be pronounced at an early and rather low stage of geological science, but are long since abandoned, and he would never have added to them suppositions which bear the character of the infancy of that science. If there is any subject to which the theory of Mr. Howorth may be applied, it is, in a figurative way, the history of the Mongols. The crowds in which they appear suddenly on the stage resembles the outpouring of volcanic matter from a hidden source, and the flood of them which soon inundated immense regions, "mixed with the ingredients over which it poured," may indeed be compared to the action of a sweeping wave. But the laws which govern the movements of mankind have but a very distant relation to those which can be discerned in the changes of the physical conditions of the surface of the globe.

F. Baron Richthofen.

Bonn, *May*, 1882.

III.—Traces of a Great Post-Glacial Flood.

3. The Evidence of the Valley Terraces.

By H. H. Howorth, F.S.A.

THE Terraces which are so conspicuous in many valleys of Western Europe, and have been largely studied in France and Britain, have given rise to a great deal of discussion. The polemics which they have suggested have been not merely about details, but about fundamental principles, and it is these fundamental principles which are still unsettled and awaiting a solution. In England at all events it may be said that every solution which is current, and there are many, fails to meet the facts, and the majority of them are singularly suggestive of the dangers of Deductive methods of reasoning. So long as we start with a mere scholastic premise that Uniformity of action is the only method pursued by Nature, and having thus committed ourselves, try to bring the facts within this rigid rule, so long are we necessarily inspiring our witnesses with the answer we wish them to give us, and so long shall we experience inevitable disappointment when some obstinate fact refuses to submit to our self-imposed rule. We shall in the following examination of the problem entirely discard this a priori theological method of discussion, and lean to whatever conclusion the facts themselves impose upon us. We must necessarily begin with a somewhat elementary position.

A river as a mechanical agent performs two entirely opposite kinds of work upon its own channel. Where its fall is great and